The Condition of South Carolina's Estuarine and Coastal Habitats During 2001-2002

an

Interagency Assessment of South Carolina's Coastal Zone

Technical Report No. 100

South Carolina Department of Health and Environmental Control

The Condition of South Carolina's Estuarine and Coastal Habitats During 2001-2002

Technical Report

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Cover photo by Phillip Jones, SCDNR

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1. INTRODUCTION

South Carolina's extensive estuarine and coastal waters represent an extremely valuable state resource that must be protected to ensure both the viability of the state's commercial and recreational fishery resources as well as the general health of these ecosystems for recreational use and quality of life for future generations. Estimates on the economic impact of the state's saltwater recreational and commercial fisheries alone exceeds 650 million dollars (SCDNR, unpublished), and almost all of the species harvested utilize estuaries for some portion of their life cycle. In addition, the beauty and quality of South Carolina's coastal zone is a major attraction to both the citizens of the state and visitors, who contribute more than 14 billion dollars in travel and tourism economic activity (World Travel and Tourism Council, 2001). The population growth in South Carolina has been considerable, with an increase of more than 500,000 people living in the state from 1990 to 2000 (SC Budget and Control Board, 2004). Growth in the coastal counties alone is projected to increase from the 2000 census of 574,956 people to 996,680 people by 2025 (SC Budget and Control Board, 2004), which represents a 73% increase in coastal growth. The construction of infrastructure (e.g., roads, commercial development, residential housing, industry) that accompanies human development will alter the rate and volume of freshwater inflow as well as the type and amount of pollutants introduced into estuaries (Fulton *et al*., 1993; Mallin *et al*., 2000). Therefore, increased coastal growth has a high potential to seriously impact South Carolina's coastal environment.

The South Carolina Estuarine and Coastal Assessment Program (SCECAP) was initiated in 1999 as a collaborative program between the South Carolina Department of Natural Resources (SCDNR) and the South Carolina Department of Health and Environmental Control (SCDHEC). The goal of SCECAP is to monitor the condition of the state's estuarine habitats to determine the proportion of the coastal zone that meets desired criteria with respect to water quality, sediment quality, and biotic condition. SCECAP supplements and compliments numerous ongoing monitoring programs being conducted by the SCDNR and SCDHEC in our coastal habitats and provides a more comprehensive assessment of the overall health of these habitats that may change with increasing coastal development. Data collected by this program are also useful for comparison with site-specific studies in areas where there are concerns about habitat condition. Finally, SCECAP represents an expansion of SCDHEC's "Ambient Surface Water Quality Monitoring Network" by (1) increasing the number of sites monitored in the coastal zone each year, (2) adding more environmental and biological measures than are normally collected in SCDHEC's monitoring network, and (3) adding monitoring sites in tidal creek habitats, which serve as important nursery habitat for most of the economically valuable species. Many of these tidal creeks are the first point of entry for runoff from upland areas and therefore provide an early indication of anthropogenic stress (Holland *et al.*, 1997; Sanger *et al.*, 1999a, b; Lerberg *et al.*, 2000; Van Dolah *et al.*, 2000, 2002a).

Development of the SCECAP monitoring network is described by Van Dolah *et al.* (2002a, b) and includes other agencies as part of the cooperative effort. The primary federal cooperators are the U.S. Environmental Protection Agency (USEPA), which has provided much of the funding for this program through the National Coastal Assessment Program, and the National Oceanic and Atmospheric Administration (NOAA) Center for Coastal Environmental Health and Biomolecular Research (CCEHBR). CCEHBR has provided technical analytical services related to sediment and tissue contaminants and their effects on biota. Other sources of support for SCECAP include the U.S. Fish and Wildlife Service (USFWS) through their "Federal Aid in Sport Fish Restoration Program" and from SCDHEC's Office of Ocean and Coastal Resource Management (OCRM), which has supported sampling supplemental sites and report printing.

This technical report is the second of a series planned to provide periodic updated information on the condition of South Carolina's estuarine habitats. The report describes our findings from the 2001-2002 sampling period and compares conditions observed in those years with conditions observed in the 1999-2000 survey (Van Dolah *et al.,* 2002a, b). The report also includes newly modified indices of habitat condition at each site and for the estuarine and coastal waters of the whole state. As a result, changes in overall coastal condition over the four-year period of this program have been re-evaluated in this report using these new indices.

2. METHODS

The sampling and analytical methods used for SCECAP are fully described in the first SCECAP report covering the 1999-2000 survey (Van Dolah *et. al.,* 2002a). This report and associated data can be viewed and downloaded from the SCDNR's SCECAP web site (http://www.dnr.state.sc.us/marine/scecap). Descriptions of the SCECAP sampling design, parameters sampled, and general analytical approach are summarized in the following sections. In general, this program utilizes methods consistent with SCDHEC's water quality monitoring programs (SCDHEC, 2001a) and the USEPA's National Coastal Assessment Program (USEPA, 2001; in review).

2.1. Sampling Design

Approximately 60 stations were selected for sampling each year, with all sites located in the coastal zone extending from the saltwater-freshwater interface to near the mouth of each estuarine drainage basin. Sampling areas extended from the Little River Inlet at the South Carolina - North Carolina border to the Wright River near the South Carolina - Georgia border. The Savannah River has not been sampled by SCECAP to date, but this river is being sampled by the Georgia DNR Coastal Resources Division as part of the USEPA National Coastal Assessment Program.

Approximately half of the stations were located in tidal creeks and the other half were located in the larger open water bodies that form South Carolina's tidal rivers, bays and sounds. Tidal creeks are defined as those estuarine water bodies less than 100 m wide from marsh bank to marsh bank. Portions of the state's coastal waters that are too shallow to sample at low tide were excluded from the station selection process, such as the headwater portions of tidal creeks with less than 1 m of water at low tide, and intertidal areas such as mud flats and vegetated salt marsh. All stations had to have a minimum water depth of 1 m since some sampling components required visits that cannot be limited by tidal stage, and other sampling components are limited to periods within three hours of low tide. Based on the coastal maps developed for SCECAP to define the boundaries of tidal creeks and open water habitats suitable for sampling by this program, approximately 17% of the state's estuarine waters represent creek habitat and the remaining 83% represent the larger open water areas.

Stations within each habitat type were selected using a probability-based, random tessellation, stratified sampling design (Stevens, 1997; Stevens and Olsen, 1999), with new station locations picked each year. Actual sampling locations were recorded using a Global Positioning System (GPS).

All stations were sampled once during the summer months (mid June through August) for the core-monitoring program described in this report. The summer period was selected since it represents a period when some water quality variables may be limiting to biota and it is a period when many of the fish and crustacean species of concern are utilizing the estuary for nursery habitat. Most of the measures were collected within a 2-3 hr time period; however, some of the water quality data include time-series measures collected over a longer time period (up to 25 hrs). Approximately 30 of the sites selected for each year (15 tidal creek and 15 open water) were sampled monthly by SCDHEC for most water quality measures (except dissolved nutrients and TSS) to collect a full 12 months of data for each site. The results of that sampling effort will be provided in another report.

A limited number of sites were also selected non-randomly for sampling during 2001-2002. These sites were generally located in areas suspected to be impacted by land use activities.

2.2. Water Quality Measurements

Water quality measurements and samples were generally collected prior to deployment of other sampling gear to ensure that bottom disturbance did not affect these measures. Near-surface (0.3 m depth) and near-bottom (0.3 m above bottom) instantaneous measurements of dissolved oxygen, salinity, and temperature were collected using Yellow Springs Instrument (YSI) Inc. Model 85 water quality meters. Near-surface measures of pH were collected using a pHep® 3 field microprocessor meter. More complete time-profile measurements of all four parameters were obtained from the near-bottom waters of each site using YSI Model 6920 multiprobes logging at 15 min intervals for a minimum of 25 hrs to record readings over two complete tidal cycles.

Water quality samples included near-surface measures of nitrogen, including ammonia, nitrate/nitrite and total Kjeldahl nitrogen (TKN), total phosphorus, total organic carbon (TOC), total suspended solids, turbidity, five-day biochemical oxygen demand (BOD_5), chlorophyll-a, and fecal coliform bacteria concentrations. Near-surface measures of dissolved nutrients were also collected, including ammonia, inorganic nitrogen (DIN), organic nitrogen (DON), inorganic phosphorus (orthophosphate or OP), organic phosphorous (DOP), and silica (DS). All samples were collected by inserting pre-cleaned water bottles to a depth of 0.3 m, inverting, and then filling the bottle directly at that depth. Dissolved nutrient samples were filtered in the field through a 0.45 µm pore cellulose acetate filter. The bottles were then stored on ice until brought to the laboratory for further processing. Total nutrients, TOC, total alkalinity, TSS, turbidity, BOD_5, chlorophyll-a and fecal coliform bacteria samples were processed by SCDHEC using standardized procedures (SCDHEC, 1997, 1998b, 2000, 2001a). Dissolved nutrients were processed through the University of South Carolina using a Technicon AutoAnalyzer and standardized procedures described by Lewitus *et al.* (2003, 2004a). DON and DOP were calculated by subtracting total inorganic from total dissolved N or P, measured by the persulfate oxidation technique (D'Elia *et al.,* 1977).

2.3. Biological and Sediment Sampling

Bottom sediment samples were collected at each station using a stainless steel 0.04 m^2 Young grab deployed from an anchored boat, with the boat repositioned between each sample to ensure that the same bottom was not sampled twice, and to spread the samples over a 10-20 m^2 bottom area. The grab was thoroughly cleaned prior to field sampling and rinsed with isopropyl alcohol between stations. Three of the grab samples were washed through a 0.5 mm sieve to collect the benthic invertebrate fauna and then preserved in a 10% buffered formalin-seawater solution containing rose bengal stain. The surficial sediments (upper 3 cm) of the remaining grab samples were homogenized on site and placed in pre-cleaned bottles for analysis of sediment composition, contaminants, and sediment toxicity. All sediment samples were kept on ice while in the field, and then stored either at 4°C (toxicity, porewater) or frozen (contaminants, sediment composition, TOC) until analyzed.

Particle size analyses were performed using a modification of the pipette method described by Plumb (1981). Pore water ammonia was measured using a Hach Model 700 colorimeter and TOC was measured on a Perkin Elmer Model 2400 CHNS Analyzer.

Contaminants measured in the sediments included 15 metals, 25 polycyclic aromatic hydrocarbons (PAHs), 30 polychlorinated biphenyls (PCBs), and 23 pesticides. All contaminants were analyzed by the NOAA-NOS CCEHBR laboratory using procedures similar to those described by Krahn *et al.* (1988), Fortner *et al.* (1996), Kucklick *et al.* (1997), and Long *et al.* (1997).

Sediment toxicity was measured using three bioassays. They included the Microtox® assay using a photoluminescent bacterium, *Vibrio fischeri*, and protocols described by the Microbics Corporation (1992); a 7-day juvenile clam growth assay using *Mercenaria mercenaria* and protocols described by Ringwood and Keppler (1998); and 10-day whole sediment amphipod assay using *Ampelisca abdita* and protocols described by ASTM (1993). Toxicity in the Microtox assay was based on criteria described by Ringwood *et al.* (1997, criterion #6). For the clam assay, sediments were considered toxic if growth (dry weight) was < 80% of that observed in control sediments and there was a statistically significant difference ($p < 0.05$). For the amphipod assay, sediments were considered toxic if survival was < 80% of that observed in control sediments and the difference was statistically significant ($p < 0.05$).

Two of the three grab samples collected to assess benthic community samples were sorted in the laboratory to separate organisms from the sediment remaining in the sample for analysis of the invertebrate community composition. The remaining grab sample was held in reserve. All organisms from the two grabs were identified to the species level, or the lowest practical taxonomic level possible if the specimen was damaged or too immature for accurate identification. A reference collection of all benthic species collected for SCECAP is being maintained at the SCDNR Marine Resources Research Institute.

Fish and large crustaceans (primarily penaeid shrimp and blue crabs) were collected at each site following the benthic sampling to evaluate community composition. Two replicate tows were made at each site using a 4-seam trawl (5.3 m foot rope, 4.4 m head rope and 1.9 cm bar mesh throughout). Trawl tow lengths were standardized to 0.5 km for open-water sites and 0.25 km for creek sites. Tows were made only during daylight hours with the current, and boat speed was standardized as much as possible. Tows made in tidal creeks were limited to periods when the marsh was not flooded (approx. 3 hrs $\pm$ mean low water). This limitation was also generally applied to open water sites. Catches were sorted to lowest practical taxonomic level, counted, and checked for gross pathologies, deformities or external parasites. All organisms were measured to the nearest centimeter. When more than 25 individuals of a species were collected, the species was sub-sampled. Mean abundance and biomass of finfish and crustaceans were corrected for the total area swept by the two trawls, using the formula described by Krebs (1972).

Fish tissue samples were obtained for contaminant analyses. Species targeted included silver perch (*Bairdiella chrysoura*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonius undulatus*), and weakfish (*Cynoscion regalis*). All fish samples were wrapped in foil and stored on ice in plastic bags until they could be frozen at the laboratory. Whole fish were rinsed and then homogenized in a stainless steel blender for contaminant analyses. Extraction and analytical procedures were similar to those described for sediments.

2.4. Habitat Evaluation

Observations were made at each site prior to departure to document the presence of litter (within the limits of the trawled area), and to note the proximity of the site to urban/suburban development, industrial development, or marinas/private docks.

2.5. Quality Assurance

The SCECAP survey includes a rigorous quality assurance and quality control program to ensure that the database is of high quality. A copy of the Quality Assurance Project Plan is maintained at the SCDNR Marine Resources Research Institute and has been approved by the USEPA National Coastal Assessment Program. In addition, site visits and quality assuarance audits were conducted by partner agencies such as the USEPA.

2.6. Data Analyses

Comparisons of most water quality, sediment quality and biological measures were completed using standard parametric tests or non-parametric tests where the values could not be transformed to meet parametric test assumptions. Only the randomly located stations (station number designated as RT or RO) were included in these analyses. Since our primary comparisons were between tidal creek and open water habitats, a t-test or non-parametric Mann-Whitney U test was typically used. Comparisons involving more than two station groups or multiple years were generally completed using ANOVA or Kruskal-Wallis non-parametric tests.

Use of the probability-based sampling design provides an opportunity to statistically estimate, with confidence limits, the proportion of South Carolina's overall creek and open water habitat that falls within ranges of values that were selected based either on (1) state water quality criteria, (2) historical measurements collected by SCDHEC from 1993-1997 in the state's larger open water bodies (SCDHEC, 1998a), or (3) other thresholds indicative of stress based on sediment chemistry or biological condition (Hyland *et al*., 1999; Van Dolah *et al.,* 1999). These estimates are obtained through analysis of the cumulative distribution function (CDF) using procedures described by Diaz-Ramos *et al*. (1996). Only the randomly located, probability-based stations were included in these analyses. The sampling goal for each year was a minimum of 30 stations per habitat type in order to achieve the desired statistical confidence limits.

3. RESULTS AND DISCUSSION

Data obtained from the 2001 – 2002 survey are summarized in the following sections. More extensive data summaries are also available on the SCECAP web site (http://www.dnr.state.sc.us/marine/scecap) and are referenced in this report as "data online."

3.1. Station Array

Samples were successfully collected from 60 sites in 2001 and 64 sites in 2002. Sixty of the sites were tidal creeks, and are designated as RT (random tidal creek site) or NT (non-random tidal creek site). Sixty-four sites were in larger open water bodies, and are designated as RO (random open water site) or NO (non-random open water site). Specific site locations and sampling dates are provided in Figures 3.1.1 - 3.1.4 and Appendix 1. Five of the sites sampled in 2001 and two of the sites sampled in 2002 were not randomly located stations using the probability-based sampling design. Most of these stations (designated as NT or NO) were selected to target areas that were likely to be degraded. Therefore, comparisons of average conditions among habitats or between surveys (99-00 vs 01-02) do not include these sites. Two additional special area study sites sampled in 2002 (RT022282, RO026290) are included in the habitat and survey period comparisons since they are random, probability-based sites, but they are not included in our state-wide assessments using the CDF analyses because they are part of a supplemental study specifically for the Charleston Harbor estuary. The CDF analyses used a total of 55 tidal creeks and 60 open water sites.

The average depth of the open water sites sampled during the two-year period was 5.1 m and ranged from approximately 1 – 18 m (Appendix 1 and data online). Average depth of the tidal creek sites was 3 m and ranged from approximately 1 to 7 m.

3.2. Water Quality

Although instantaneous measures of basic water quality variables (temperature, salinity, dissolved oxygen, pH) were obtained during the primary visit to each site, the continuous measures of these parameters from the 25-hr instrument deployments provide the most comprehensive information because they include numerous measures during both day and night over two complete tidal cycles. Therefore, these data are used as the primary data set in our analyses of these four water quality parameters. The other measures of water quality (total and dissolved nutrients, BOD_5, TSS, turbidity, TOC, total alkalinity, chlorophyll-a, and fecal coliform bacteria) obtained at each site represent instantaneous measures collected during the primary site visit.

The SCDHEC has developed State regulations 61-68 and 61-69 to protect the water quality of the state (SCDHEC, 2001b). The water quality standards include numeric and narrative criteria that are used for setting permit limits on discharges to waters of the state, with the intent of maintaining and improving surface waters "to a level to provide for the survival and propagation of a balanced indigenous aquatic community of flora and fauna and to provide for recreation in and on the water." Occasional short-term departures from these conditions will not automatically result in adverse effects to the biological community. The standards also recognize that deviations from these criteria may occur due solely to natural conditions and that the aquatic community is adapted to such conditions. In such circumstances, the variations do not represent standards violations, and critical conditions of the natural situation, e.g., low flow, high temperature, minimum dissolved oxygen, etc., are used as the basis of permit limits.

All data collected by SCECAP from field observations and water samples are related to water quality standards for the state's saltwater regions (SCDHEC, 2001b) where possible. Because SCECAP samples are limited to a summer index period and generally do not include multiple samples over time, the data are not appropriate for use in USEPA 303(d) or 305(b) reporting requirements. Additionally, there are no USEPA or state water quality standards for many of the parameters

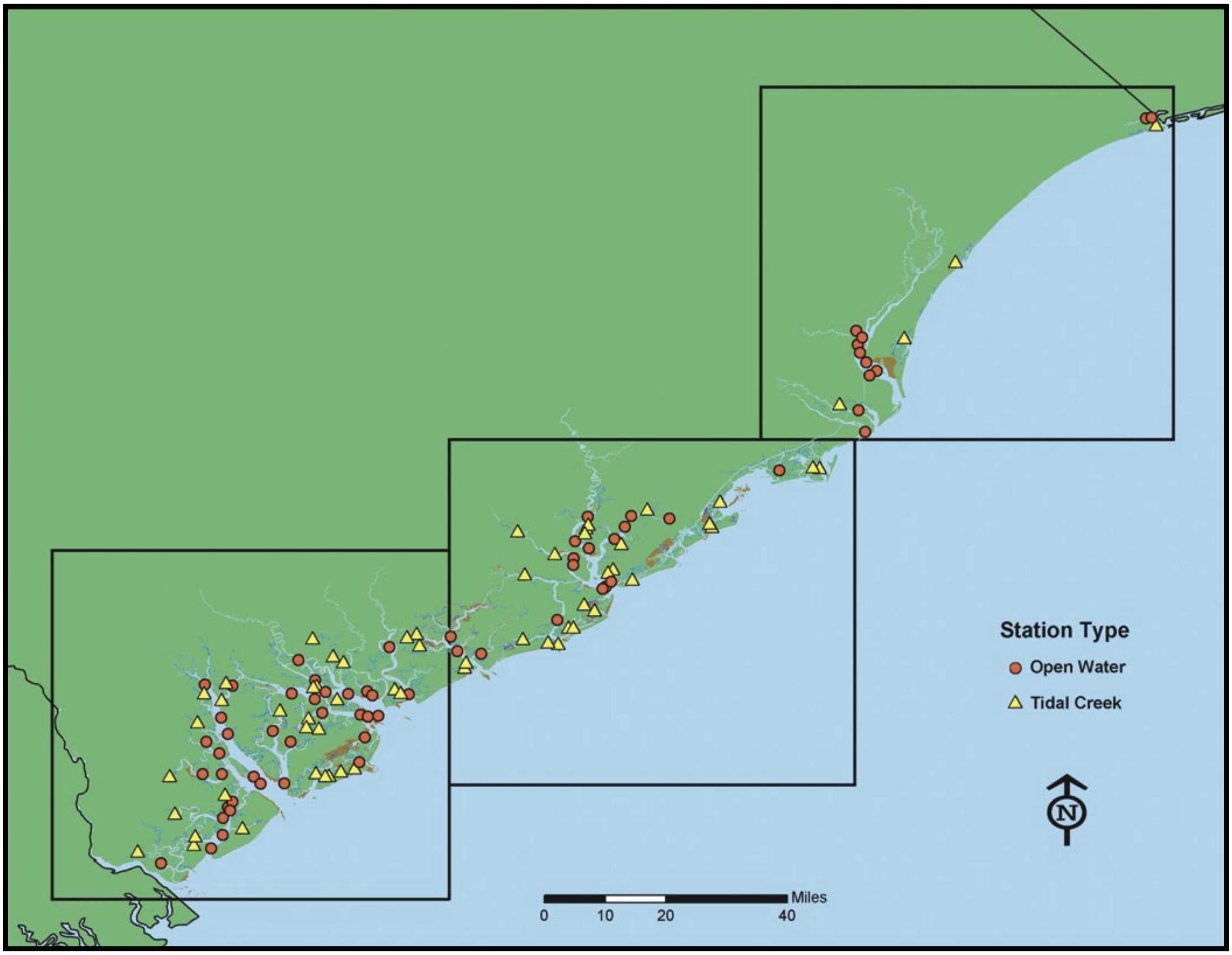


Figure 3.1.1. Distribution of open water and tidal creek stations sampled throughout South Carolina's coastal zone during 2001 – 2002. Brown represents shallow areas that cannot be sampled using SCECAP protocols, and dark blue represents area designated as tidal creek habitat.

measured in this program. For those measures, values are compared to data compiled for a 5-year period (1993-1997) by the SCDHEC Bureau of Water in their routine statewide Ambient Surface Water Quality Monitoring Network (SCDHEC, 1998a). For this report, values exceeding the 75th percentile of all values measured (≥ method detection limit) in the state's saltwater habitats indicate evidence of elevated concentrations and values exceeding the 90th percentile of all saltwater measures indicate high concentrations. The SCDHEC historical database on water quality was primarily obtained from larger open water bodies. Therefore, caution should be used in interpreting data obtained from tidal creek sites since high or low values observed for some parameters may represent "normal" conditions. For some water quality variables, such as dissolved nutrients and chlorophyll-a, criteria or guidelines published in other reports are used for comparison of conditions (e.g. Bricker *et al*., 1999; USEPA, in review) since no appropriate SCDHEC data were available.

Temperature

Temperature data are collectd primarily to relate with other water quality variables that are affected by this parameter. The average bottom water temperature based on the continuous 25-hr data collected at each site was 29.3 ^{o}C for both the tidal creek and open water sites. This average was very comparable to the average temperatures observed in each habitat during

Figure 3.1.2. Distribution of open water and tidal creek stations sampled in the northern portion of the state during 2001–2002. Brown represents shallow areas that cannot be sampled using SCECAP protocols, and dark blue represents areas designated as tidal creek habitat.

the 1999-2000 survey (Van Dolah *et al*., 2002a). The range of mean bottom temperatures during 2001-2002 was 26.0 to 31.8 °C among the tidal creek sites and 26.4 to 31.1 °C among the open water sites (data online). The slightly greater variation in average bottom water temperature observed in the tidal creek habitats compared to the open water sites reflects the effects of solar heating on these shallow water sites. The instantaneous surface and bottom temperatures showed similar ranges and differences between habitats. The average difference between surface and bottom temperatures measured in either habitat type was ≤ 0.2 °C during both sampling years. Fauna inhabiting South Carolina estuaries are generally well adapted to the temperature ranges observed in this program.

Salinity

Salinity influences the distribution and diversity of many invertebrate and fish species. Changes in salinity at a site can also provide a measure of stressful conditions if there is a large variation in concentrations over short time periods. The average bottom salinity of all tidal creek sites sampled during the 2001 – 2002 survey was 30.6 ppt and ranged from 9.5 to 37.4 ppt (data online). The average bottom salinity among the open water sites was 29.5 ppt and ranged from 10.0 to 38.1 ppt. The salinities observed during this survey period were slightly greater than those observed in 1999 – 2000 (Van Dolah *et al.,* 2002a, c), with 73% of the creek habitat and 63% of the open water habitat having an average bottom

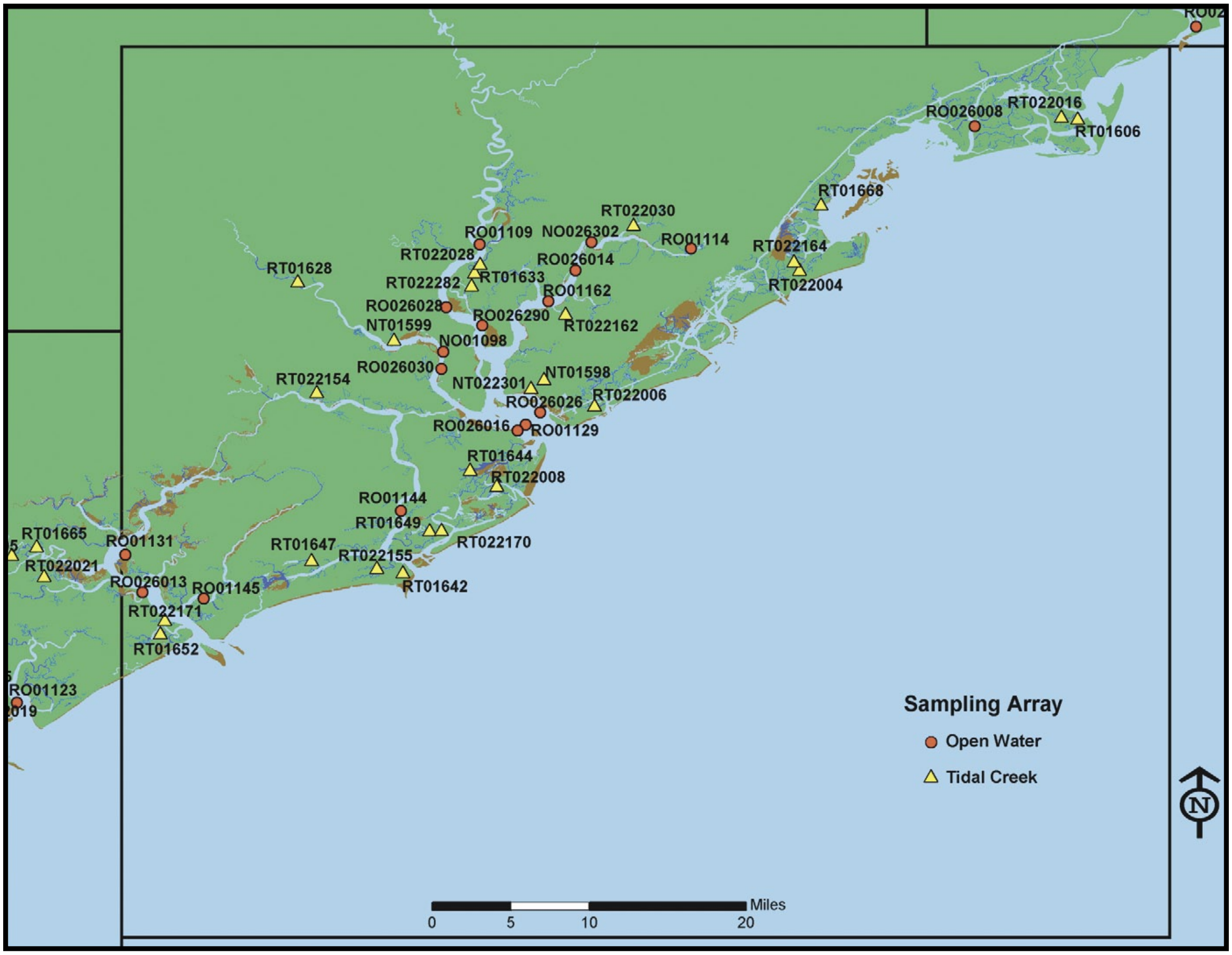


Figure 3.1.3. Distribution of open water and tidal creek stations sampled in the central portion of the state during 2001 – 2002. Brown represents shallow areas that cannot be sampled using SCECAP protocols, and dark blue represents areas designated as tidal creek habitat.

salinity of > 30 ppt (Figure 3.2.1). This represents near full-strength seawater and reflects the effects of severe drought conditions that persisted throughout this sampling period. There was no significant difference between bottom salinities observed at the creek versus open water sites ($p = 0.06$).

As with temperature, the mean difference between the instantaneous surface and bottom salinities was relatively small (≤ 0.5 ppt for the tidal creeks and ≤ 1.2 ppt for the open water sites) within each year (data online). Salinity ranges observed at each site were also generally less than 15 ppt, except at four open water and five tidal creek sites. Two of those sites (RO01108 and RO01130) had greater than a 20 ppt range in salinity, which may represent stressful conditions (Holland *et al*., 2004). Until additional data are available, no criteria have been established by the SCECAP program to identify stressful conditions using salinity.

Dissolved Oxygen

Dissolved oxygen (DO) is one of the most critical water quality parameters measured in this program. Low dissolved oxygen conditions can limit the distribution or survival of most estuarine biota, especially if these conditions persist for extended time periods (see Diaz and Rosenberg, 1995; USEPA, 2001 for reviews). Dissolved oxygen criteria established by the SCDHEC for "Shellfish

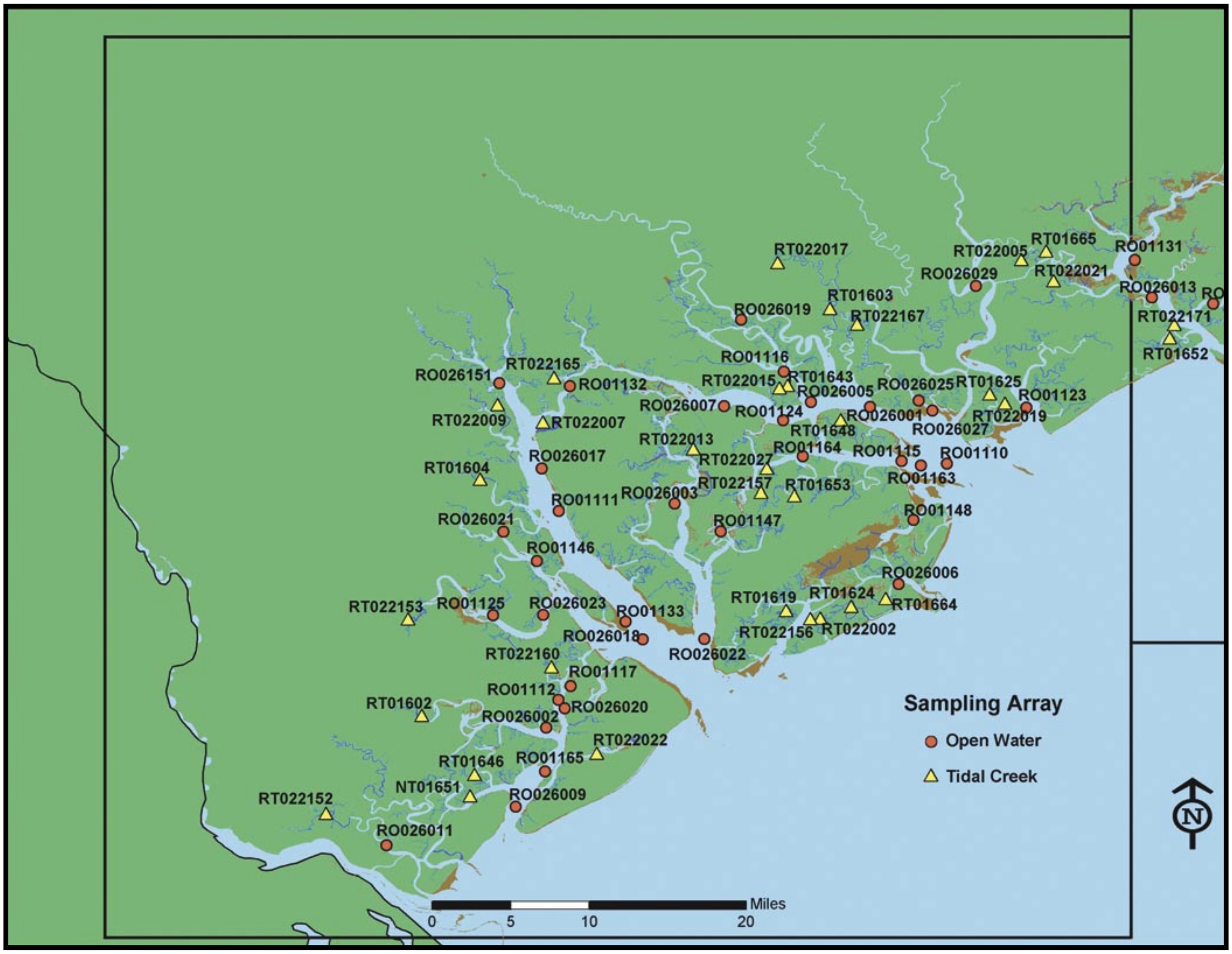


Figure 3.1.4. Distribution of open water and tidal creek stations sampled in the southern portion of the state in 2001 – 2002. Brown represents shallow areas that cannot be sampled using SCECAP protocols, and dark blue represents areas designated as tidal creek habitat.

Harvesting Waters" (SFH) and Class SA saltwaters are a daily average not less than 5.0 mg/L and a low of 4.0 mg/L (SCDHEC, 2001b). Class SB waters should have dissolved oxygen levels not less than 4.0 mg/L. Since the SCECAP program was designed to sample only during a summer index period when DO levels are expected to be at their lowest, DO measurements collected in this program probably represent short-term worst-case conditions that may not reflect conditions during other seasons or longer time-averaging periods. However, SCECAP data provide useful measures of average DO concentrations observed in South Carolina's coastal habitats when DO levels may be limiting, and it identifies areas within the state where this is occurring. For the purposes of this study, mean or instantaneous DO concentrations > 4 mg/L are considered to be good for summer time periods, values < 4 mg/L and ≥ 3 mg/L are considered to be fair (i.e., contravenes one portion of the state standards), and average or instantaneous measures < 3 mg/L are considered to be poor and potentially stressful to many invertebrate and fish species.

The average bottom DO concentration at the open water stations during the 2001 – 2002 survey was 5.0 mg/L, with approximately 89% of the state's open water habitat having a mean DO ≥ 4.0 mg/L based on the 25-hr instrument deployments (Figure 3.2.2; data online). Only one open water site (representing

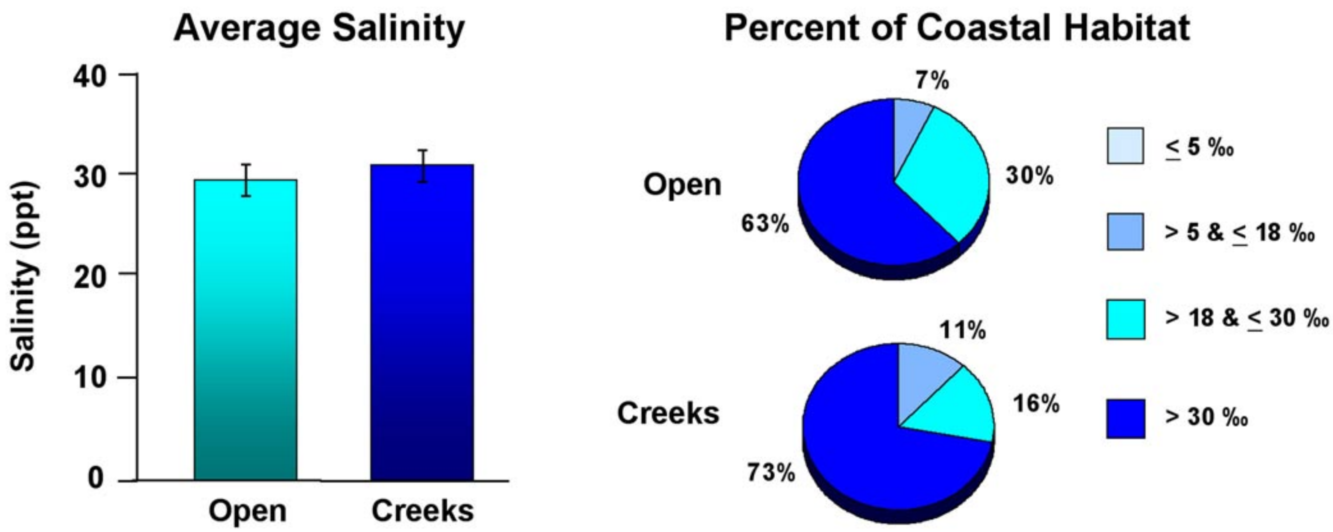


Figure 3.2.1. Comparison of the average bottom salinity concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat that represented various salinity ranges based on the average of bottom measurements obtained over 25-hrs at each station.

approximately 3% of the state's open water habitat) had an average DO < 3.0 mg/L (RO01147). This site also had an instantaneous bottom DO < 3.0, with a surface water DO concentration of 4 mg/L.

The average bottom DO concentration observed at tidal creek sites was 4.5 mg/L, with 78% of this habitat having a mean DO value ≥ 4 mg/L. The difference in mean DO values observed among the creek versus open water sites was highly significant ($p < 0.001$). Approximately 9% of the state's tidal creek habitat had mean DO levels < 3.0 mg/L and 13% of this habitat had DO levels ≥ 3 and < 4 mg/L. The mean values observed in creek and open water sites were similar to those observed during 1999-2000. In both survey periods, tidal creek sites generally had a much greater range in DO concentrations than the open water sites, as well as a higher percentage of sites with marginal or poor DO.

Although numeric state DO standards apply to all waters, the SCECAP data suggest that lower DO concentrations in tidal creeks may be normal during the summer months compared to larger water bodies. When making regulatory decisions in such situations, the practice of considering natural background conditions seems appropriate. Even so, creek sites with the mean DO levels < 3 mg/L may not fully support biological assemblages inhabiting those sites, especially during periods when DO levels are less than 2 mg/L (hypoxic conditions). Hypoxic conditions are known to be limiting to many estuarine and marine biota (Gibson *et al*., 2000).

The instantaneous measures of bottom DO were, on average, slightly lower than the mean DO values obtained from the 25-hr deployment of water quality meters among both the open water and tidal creek sites (data online). These differences were not statistically significant ($p > 0.1$) and a similar pattern was observed in 1999-2000 (Van Dolah *et al*., 2002a). There was also no significant difference between the surface and bottom measures when all sites were considered together within each habitat (mean differences were < 0.3 mg/L in either habitat, $p \geq 0.08$). However, as noted in the 1999-2000 survey, instantaneous DO measures resulted in a higher percentage of the state's coastal water habitat coding as fair or poor (38% vs. 22% of the tidal creek habitat and 13% vs. 11% of the open water habitat). The instantaneous bottom DO measures at each site were only weakly correlated to the mean bottom DO obtained from the 25-hr instrument deployment ($r^2 = 0.25$). While instantaneous measures of DO and other water quality parameters are the most reasonable approach for SCDHEC routine year-round assessment of coastal water quality, instantaneous measures do not appear to reflect the same DO

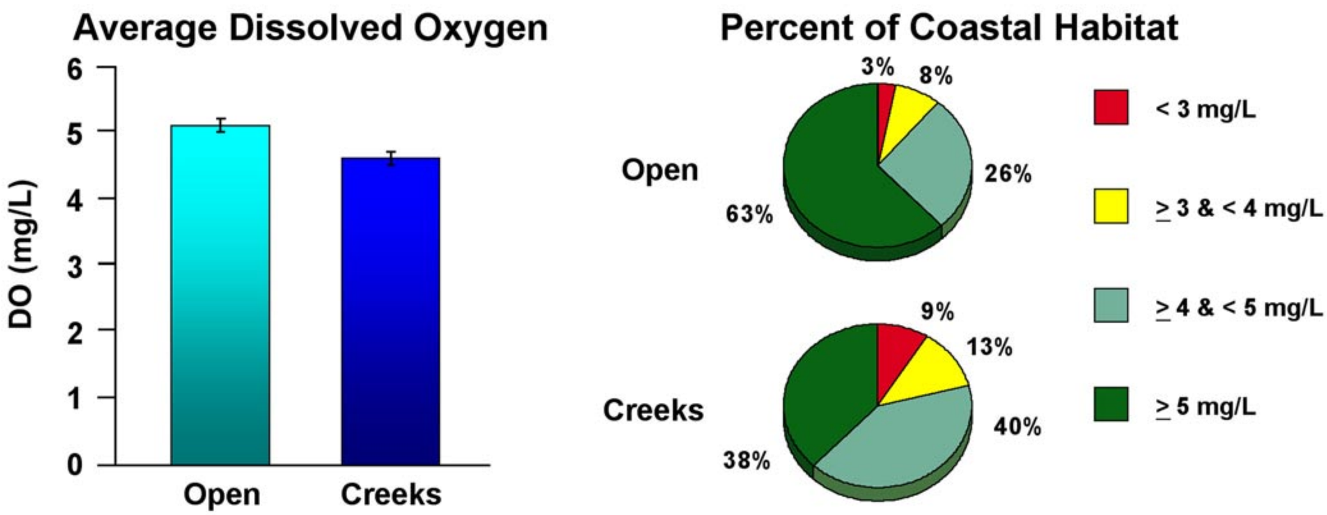


Figure 3.2.2. Comparison of the average dissolved oxygen concentrations observed in tidal creek and open water habitats during 2001 – 2002, and estimates of the percent of the state's coastal habitat representing various DO ranges based on the average of measurements obtained over 25-hrs at each station. Red indicates poor DO conditions, yellow indicates fair DO conditions but below state standards, light green represent good conditions that are considered acceptable for supporting biota during summer months, and dark green represents good conditions above the state DO standard.

conditions measured over both day and night during all tidal stages. Similarly, one summer-time measure may not accurately reflect long-term impairment of a site relative to low DO conditions.

pH

Measures of pH provide another indicator of water quality in estuarine habitats that has often been ignored by other sampling programs at the state or national level. Measures of pH are based on a logarithmic scale, so even small changes in the value can result in significant stress to estuarine organisms (Bamber, 1987, 1990; Ringwood and Keppler, 2002). Unusually low or high pH values may indicate the presence of pollutants (e.g., release of acids or caustic materials) or high concentrations of carbon dioxide (Gibson *et al.*, 2000). Because salinity and alkalinity affect the pH of estuarine waters, SCDHEC has established water quality standards that account for these effects. The pH in Class SA and SB tidal saltwater areas should not vary more than one-half of a pH unit above or below effluent-free waters in the same geologic area having a similar salinity, alkalinity and temperature, and values should never be lower than 6.5 or higher than 8.5. Shellfish Harvesting waters (SFH) should not deviate more than 0.3 units from effluent-free waters. Based on these criteria, pH criteria were established for SCECAP assessments using data collected from pristine environments sampled in 1999-2000 (e.g., Cape Romain, ACE and North Inlet National Estuarine Research Reserves, SFH class saltwaters) to identify pH levels that were considered to represent good, fair, and poor conditions for polyhaline waters (> 18 ppt; Van Dolah *et al.*, 2002a, c). For polyhaline, effluent-free waters, the average pH in the 1999-2000 study was 7.6 (Van Dolah *et al.*, 2002a). Therefore, pH levels below 7.1 are below the 0.5 pH unit variation allowed for effluent-free waters and are considered to be poor pH conditions. Values below 7.4 pH units are considered to be only fair since they represent the lower 10th percentile of all pH records observed for polyhaline waters during the 1999-2000 survey. Values ≥ 7.4 pH units are considered to be good for polyhaline waters. Criteria are still not established for lower salinity waters since the number of sites that had salinities < 18 ppt are still too limited in number due to the extreme drought conditions experienced since 1999.

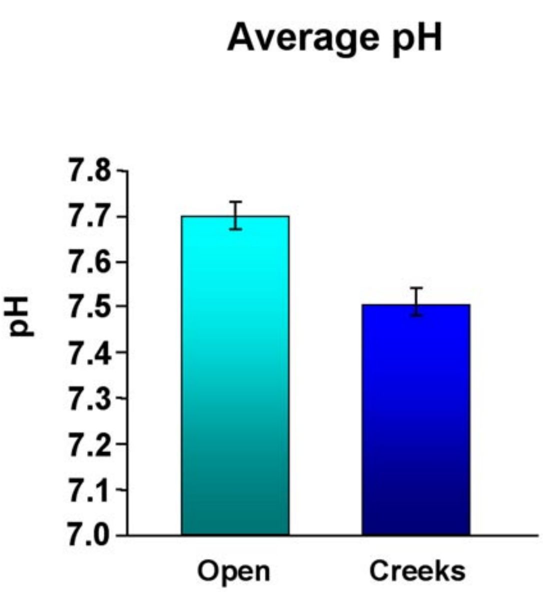
The overall average pH observed in 2001-2002 based on the 25-hr measures was 7.5 in tidal creek habitats and 7.7 in open water habitats (Figure 3.2.3, data online). The average instantaneous surface pH measures collected at all sites within each habitat type were within 0.1 pH unit of the average bottom pH based on the continuous measurements, and all average values were very similar to the averages observed in 1999-2000 (Van Dolah *et al*., 2002a, c). The difference in mean pH values was statistically significant between habitats ($p < 0.001$) with a higher percentage of the state's creek habitat having pH values considered to be only fair or poor compared to the state's open water habitat (Figure 3.2.3). A similar trend was noted in 1999-2000 (Van Dolah *et al*., 2002a). None of the stations sampled in 2001-2002 had mean or maximum values that exceeded the maximum (8.5 pH units) or minimum (6.5 pH units) criteria established by SCDHEC, at any time during the 25-hr instrument deployment period at each site (data online). Therefore, although we can't apply the SCECAP criteria to the 10 sites with average salinities less than 18 ppt, those sites at least had pH values within the maximum range accepted by SCDHEC.

Nutrients

Nutrient concentrations in estuarine waters can become high due to runoff from upland urban and suburban developments, agricultural fields adjacent to estuarine habitats, riverine input of nutrient-rich waters from inland areas, and atmospheric deposition. High nutrient levels can lead to eutrophication of estuarine waters resulting in excessive algal blooms (including harmful algal blooms), decreased dissolved oxygen, and other undesirable effects that adversely affect estuarine biota (Bricker *et al*., 1999). Currently, there are no state standards in South Carolina estuarine waters for the various forms of nitrogen (except ammonia) and phosphorus. Therefore, the SCECAP data are compared to SCDHEC's historical database (SCDHEC, 1998a) to identify waters showing evidence of elevated nutrients. Values below the 75th percentile of the historical database are considered to be normal, values above the 75th percentile and below the 90th percentile are considered to be moderately enriched, and values above the 90th percentile are considered to be highly enriched. Dissolved nutrient concentrations are also compared with guidelines identified by NOAA (Bricker *et al.*, 1999) and the USEPA (in review).

Nitrogen:

Total nitrogen (TN), as measured by the SCDHEC laboratory, is best represented by the sum of nitrate-nitrite and total Kjeldahl nitrogen (TKN). Based on historical SCDHEC (1998a) data, TN values above 1.29 mg/L are considered to be highly enriched since they represent the upper 90th percentile



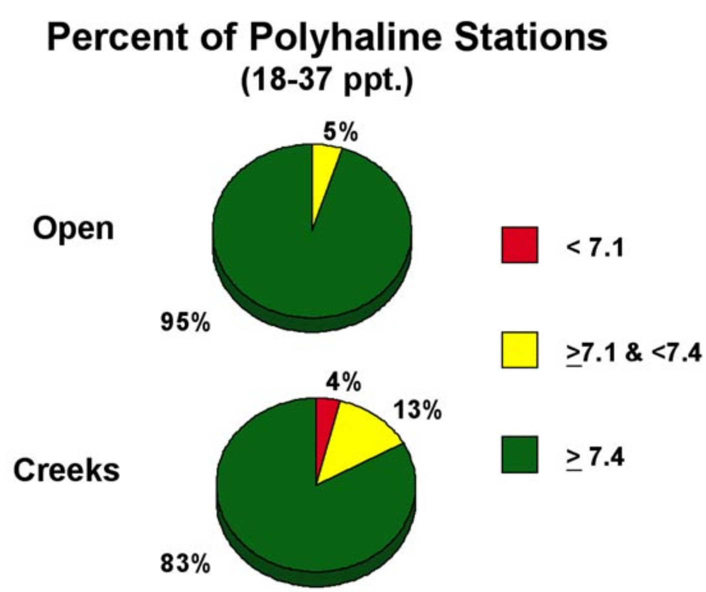


Figure 3.2.3. Comparison of the average bottom pH concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various bottom pH ranges based on the average of measurements obtained over 25-hrs at each station. Red indicates poor pH conditions below SCDHEC standards when compared to natural waters, yellow indicates fair pH conditions within the lower 10th percentile of historical pH values observed in pristine polyhaline waters, and green represents good pH relative to historical data for pristine polyhaline waters.

of the historical records. Values > 0.95 mg/L and < 1.29 are considered to be moderately enriched since they are above the upper 75th percentile of the historical records and below the 90th percentile of those records. Values ≤ 0.95 mg/L are considered to be normal. In 2001-2002, the average concentration of TN was 0.53 mg/L among the tidal creek sites and 0.47 mg/L among the open water sites (Figure 3.2.4). In contrast to the 1999-2000 survey, this difference was not statistically significant ($p = 0.159$) and the average values observed in both habitats were lower than observed in 1999-2000 (Van Dolah *et al*., 2002a. Approximately 82% of the nitrogen was in the form of TKN (organic fraction plus ammonia) when all stations were considered collectively. Average nitrate-nitrite values in the creeks and open water sites were only 0.03 and 0.07 mg/L, respectively, which was similar to the values observed in 1999-2000. Using the sum of the detectable values for nitrate-nitrite and TKN as an indication of total nitrogen (TN) enrichment, only about 3% of the state's creek habitat and 4% of the state's open water habitat had moderately elevated TN concentrations using SCECAP criteria, and ≤ 1% of either habitat had highly enriched nutrient values (Figure 3.2.4, data online). These TN values observed in 2001-2002 are comparable to those observed in open water habitats in 1999-2000 and lower than those observed during that time period in tidal creek habitats. One of the two sites with high TN values was located in a creek off the Old Chehaw River (RT01603) and the other site was located in Winyah Bay (RO01113). Only the latter station also had elevated concentrations of chlorophyll-a, another measure of possible estuarine eutrophication (see Chlorophyll-a section).

Average surface total dissolved nitrogen (TDN) concentrations in the creeks and open water sites were 0.67 mg/L and 0.64 mg/L, respectively. Four of the randomly selected creek sites (RT01603, RT01604, RT01654, RT022017), representing 7% of the state's tidal creek habitat, had TDN concentrations > 1.0 mg/L, which is considered to be high based on guidelines developed for coastal waters by NOAA (Bricker *et al.*, 1999). One non-random site (NT01651) also had high TDN, and four other randomly selected creek sites (RT01628, RT01643, RT01668, RT022152) had TDN values > 0.9 mg/L, which is close to the NOAA threshold for high TDN (data online). Several of these sites were located in watersheds with agricultural land use, and may reflect elevated nutrient runoff from these fields. None of the open water sites sampled in 2001-2002 had TDN values > 1.0 mg/L, but five sites (RO01114, RO01116, RO01148, RO026019, RO026024) had TDN values > 0.9 mg/L. The location of these sites is provided in Appendix 1. None of the sites with high TDN also had high chlorophyll-a measures, another measure of

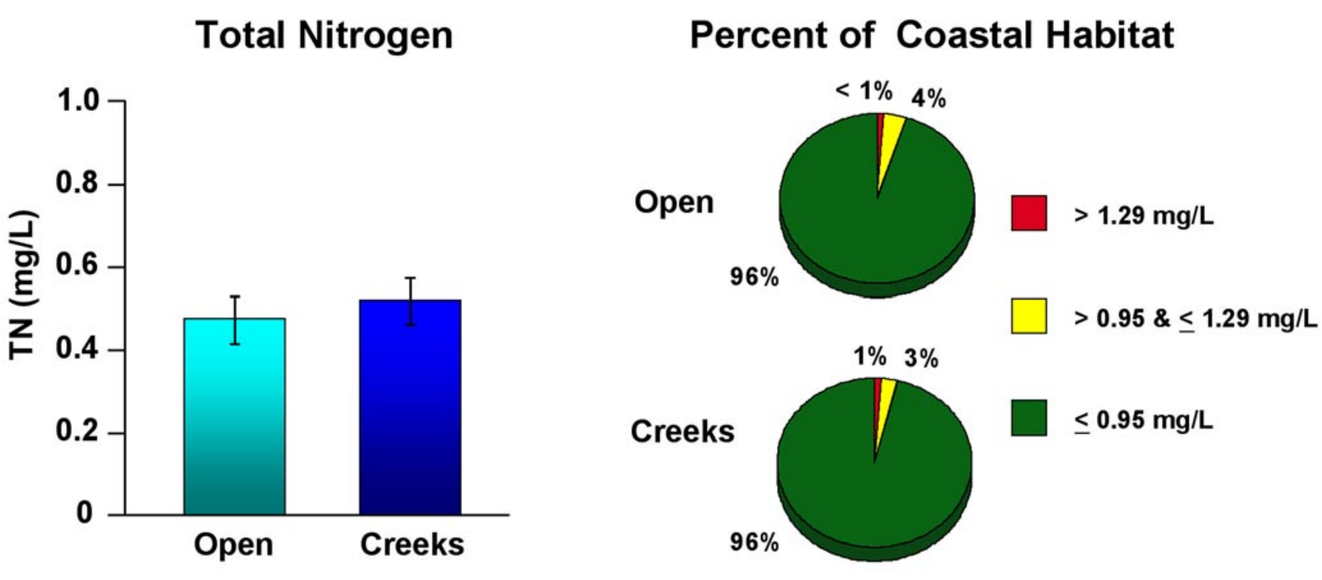


Figure 3.2.4. Comparison of the average total nitrogen (TN) concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various TN ranges that represent normal (green), moderately enriched (yellow), or highly enriched (red) values relative to SCDHEC historical data.

possible estuarine eutrophication. As noted in the section describing chlorophyll-a results, there was a very poor correlation between TDN and chlorophyll-a concentrations and this nutrient measure may not be a suitable indicator of phytoplankton abundance at the NOAA thresholds described by Bricker *et al.* (1999).

Most of the dissolved nitrogen was in the form of dissolved organic nitrogen (DON) in both habitats (81% among all sites combined; data online). Due to differences in analytical protocols used to estimate TN and TDN, combined with a high percentage of missing TN values in the 2001 data set, it is not possible to directly compare TN versus TDN values. However, based on the results obtained using the two procedures, it is likely that most of the TN measured at the SCECAP sites was in the form of TDN. Results obtained in 2000 also indicated that the majority of TN was in the form of TDN (Van Dolah *et al.*, 2002a, c).

Measures of dissolved inorganic nitrogen (DIN) provide another estimate of possible estuarine eutrophication that is being used by the USEPA (in review). In the 2001-2002 survey, the average DIN concentrations at the tidal creek and open water sites were 0.11 and 0.13 mg/L, respectively. The USEPA (in review) considers DIN values between 0.1 and 0.5 mg/L to represent fair conditions and values above 0.5 mg/L to represent poor (or enriched) conditions. In our survey, only one site (RO01112) had a DIN value > 0.5 mg/L and there was no direct positive correlation with DIN and chlorophyll-a (see chlorophyll-a section). In fact, chlorophyll-a concentrations (one measure of possible eutrophication) were generally highest at stations with very low DIN concentrations. While this could be expected due to the utilization of DIN by phytoplankton, the DIN criteria used by the USEPA do not appear to be very indicative of possible eutrophic conditions in SC waters based on other measures we collect. Most of the DIN at station RO01112 was in the form of ammonia rather than nitrate/nitrite.

Phosphorus:

Based on SCDHEC historical survey data (SCDHEC, 1998a), average total phosphorus levels > 0.17 mg/L are considered to be highly enriched since they represent the upper 90th percentile of the historical observations. Values > 0.09 and ≤ 0.17 mg/L are considered to be moderately enriched and represent concentrations above the 75th percentile and below the 90th percentile of historical records. Values ≤ 0.09 mg/L are considered to be good. The average total phosphorus concentration (TP) measured by SCDHEC in 2001-2002 was 0.073 mg/L at the creek sites and 0.058 mg/L at the open water sites (Figure 3.2.5). In contrast to the previous survey in 1999-2000, this difference was not statistically significant ($p = 0.2$) and values among the stations were generally lower. Only 5% of the state's creek habitat and 1% of the state's open water habitat had total phosphorus concentrations that exceeded the 90th percentile of the historical database collected by SCDHEC from 1993-1997 (SCDHEC, 1998a). Only four of the 20 sites with moderately enriched to highly enriched TP values also had elevated chlorophyll-a concentrations, which suggests that this measure may not be strongly related to phytoplankton enrichment in SC waters (see chlorophyll-a section).

The average total dissolved phosphorus (TDP) concentrations observed in creeks versus open water habitats were 0.039 mg/L and 0.035 mg/L, respectively, which was comparable to the values observed in 1999-2000 (Van Dolah *et al.*, 2002a). This difference was not statistically significant ($p = 0.5$). Using the NOAA guidelines (0.10 mg/L) as a measure of possible dissolved phosphorus enrichment in coastal waters (Bricker *et al.*, 1999), none of the open water sites and only three of the creek sites (RT01628, RT022017, RT022155) were enriched (data online). One of these sites, RT022017, was in the Old Chehaw River where other elevated measures of nutrients were observed. Inorganic phosphorus (orthophosphate-OP) comprised approximately 84% of the TDP when all samples were considered collectively.

Dissolved inorganic phosphorus (DIP) is used by the USEPA (in review) as another measure of possible estuarine eutrophication that may lead to undesirable phytoplankton blooms if DIP concentrations become excessive. The USEPA considers DIP levels less than 0.01 mg/L to be good for east coast estuaries. Levels between 0.01 – 0.05 mg/L are considered to be fair and concentrations greater than 0.05

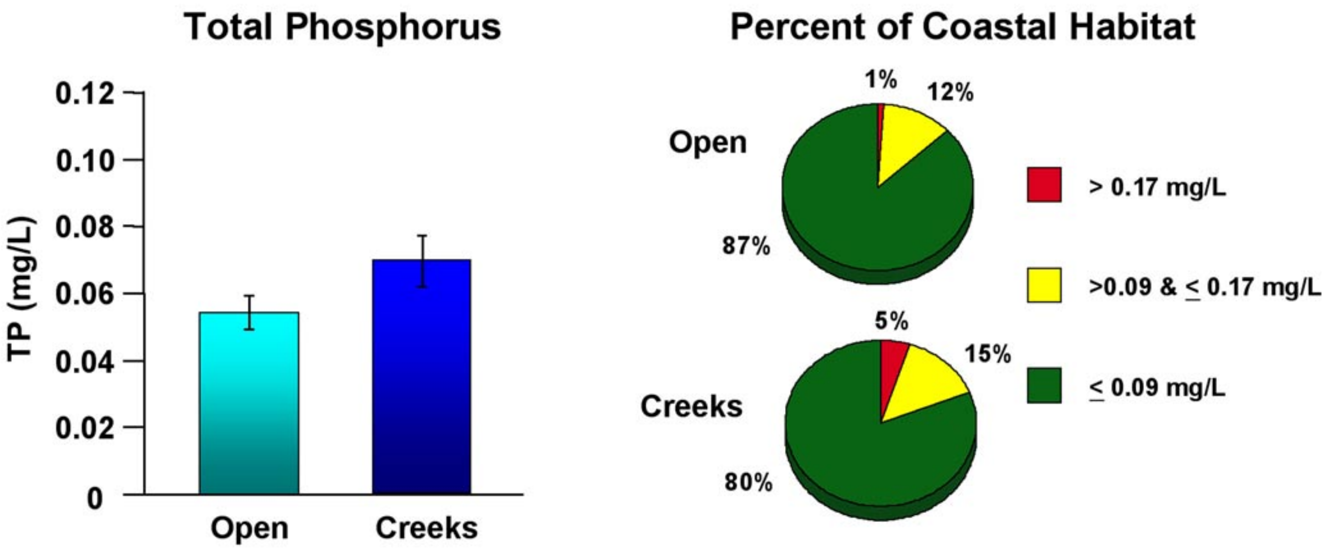


Figure 3.2.5. Comparison of the average total phosphorus (TP) concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various TP ranges that represent normal (green), moderately enriched (yellow), or highly enriched (red) values relative to SCDHEC historical data.

mg/L are considered to be poor. The average DIP concentrations observed in tidal creek and open water habitats during this survey period were 0.033 and 0.029 mg/L, respectively. Approximately 12% of the state's tidal creek habitat and 6% of the open water habitat had DIP concentrations greater than 0.05 mg/L. As noted for DIN, DIP values showed little correspondence to high chlorophyll-a concentrations, and the highest DIP concentrations that we have measured during SCECAP sampling since 2000 have generally had low chlorophyll-a concentrations (see chlorophyll-a section). While high DIP concentrations may be a useful indicator of possible estuarine eutrophication in other states or regions, the lack of any clear relationship between DIP and chlorophyll-a concentrations in South Carolina waters suggests that other nutrient measures collected by SCECAP should be given higher priority in our assessment of overall water quality.

Silica:

Dissolved silica (DS) measurements are primarily collected for the National Coastal Assessment Program. Low silica levels can be a limiting factor in the production of certain forms of phytoplankton, primarily diatoms. Average silica concentrations in the 2001-2002 survey were 1.41 mg/L at tidal creek sites and 1.07 mg/L at open water sites. These DS concentrations represent relatively high values that should not be a limiting nutrient for phytoplankton species in South Carolina waters since the ratio of dissolved inorganic nitrogen to dissolved silica at all sites (mean ratio = 0.09) was well below the 1:1 ratio considered to be critical (Day *et al.*, 1989).

Chlorophyll-a

Our measure of phytoplankton biomass in the water column is based on chlorophyll-a concentrations. Other phytoplankton pigments were also examined using HPLC analyses (see phytoplankton section). High chlorophyll-a concentrations provide an indication of possible estuarine eutrophication since phytoplankton respond rapidly to enriched nutrient concentrations and can form blooms that result in poor water quality (e.g., low DO, large DO variations) and the presence of harmful algal species. Bricker *et al.* (1999) and the USEPA (in review) consider chlorophyll-a concentrations above 20 µg/L to be high or poor, respectively. SCECAP sites with chlorophyll-a concentrations above 20 µg/L are also considered to be poor based on these studies. Chlorophyll-a values >12 µg/L represent the upper 75th percentile of all chlorophyll-a concentrations measured by the SCECAP program and are considered to be fair. Values ≤ 12 µg/L are considered to be good.

The average chlorophyll-a concentration in creek habitats was 10.2 µg/L and 10.0 µg/L at the open water sites (Figure 3.2.6). This difference was not statistically significant ($p = 0.4$) and represents relatively low concentrations based on our SCECAP database collected since 1999 (i.e., < 75th percentile). The CDF analysis indicated that only 7% of the state's open water habitat and 1% of the state's tidal creek habitat had chlorophyll-a concentrations > 20 µg/L, which is considered to be elevated by Bricker *et al.* (1999) and the USEPA (in review).

In order to evaluate whether nutrient concentrations are correlated with the chlorophyll-a concentrations observed, several regression and correlation analyses were conducted using all existing data collected by SCECAP since 1999 for TN and TP, and since 2000 for the TDN and TDP (note: dissolved nutrients were not measured by SCECAP in 1999). These analyses did not show strong relationships between any of the variables considered (Figure 3.2.7, 3.2.8), which may reflect the fact that chlorophyll-a concentrations probably reflect the effects of nutrient levels present in the waters prior to the sample collection period. Thus, synoptic samples of the two measures (i.e., nutrient vs. chlorophyll-a concentration) might not be expected to be strongly related. Nevertheless, both NOAA and the USEPA have established nutrient criteria that could lead to elevated chlorophyll-a concentrations, and we have evaluated our data to see if those relationships exist in SC waters. The comparison of TN and TP versus chlorophyll-a concentrations did not show a strong relationship (r^2 values < 0.2, Figure 3.2.7, Figure 3.2.8), with the TP relationship less correlated to chlorophyll-a than TN. Comparisons within each habitat type (not shown) did not significantly alter these relationships.

When chlorophyll-a concentrations were greater than 20 µg/L, the majority of those samples had TN concentrations > 0.5 mg/L. If additional data collected by this program support this pattern, the current thresholds representing enriched TN concentrations may be adjusted to better reflect the possibility of observing high phytoplankton concentrations. However, it is important to note that many samples with relatively high TN concentrations did not have high chlorophyll-a concentrations (Figure 3.2.7). The much weaker relationship between TP and chlorophyll-a suggests that this is not a limiting nutrient form in SC waters (Figure 3.2.8).

Comparison of TDN and TDP concentrations versus chlorophyll-a concentrations indicated that these variables were not correlated, and none of

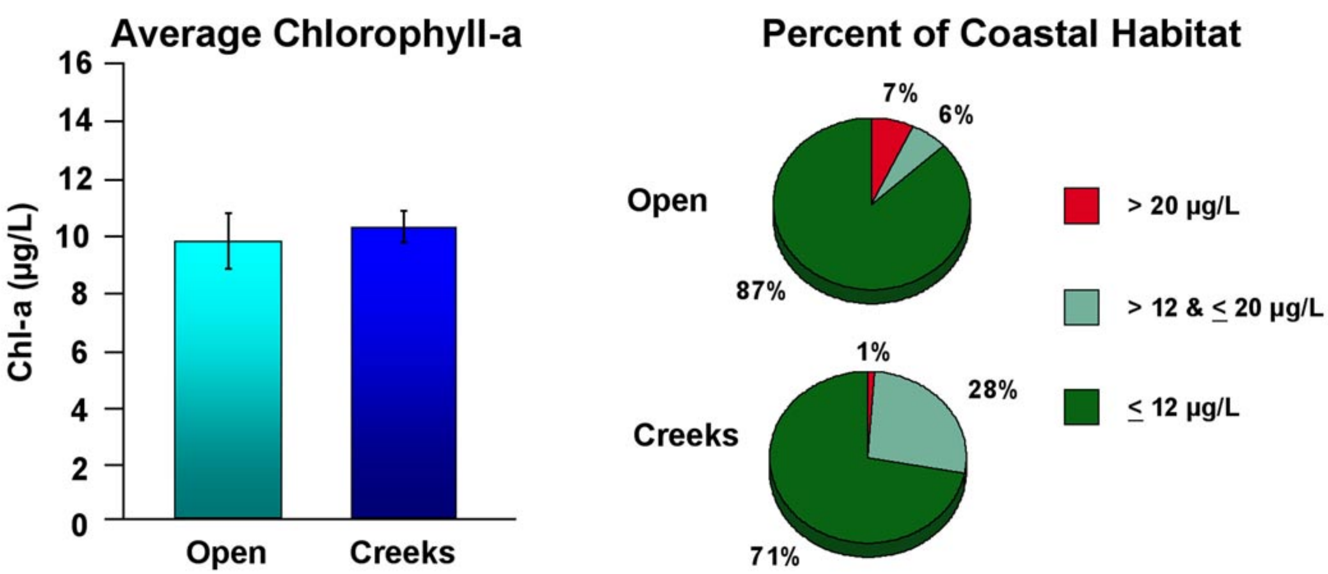


Figure 3.2.6. Comparison of the average chlorophyll-a concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various concentrations that are indicative of possible eutrophication. Red is considered to be poor (> 20 µg/L) based on criteria developed by Bricker et al. (1999) and the USEPA (in review), light green represents fair values that are above the 75th percentile of the SCECAP data for this parameter, and dark green represents low to normal chlorophyll-a values.

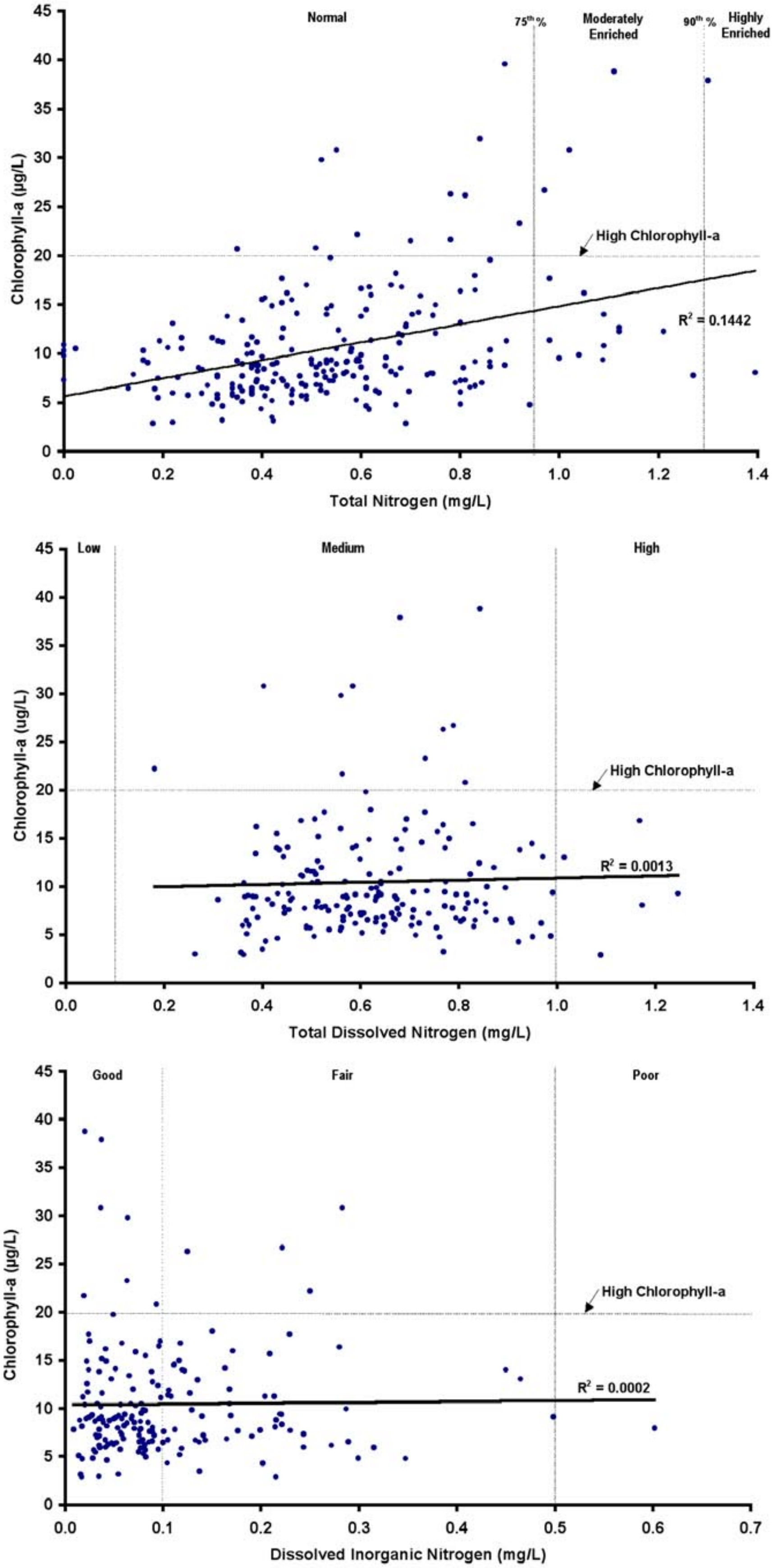
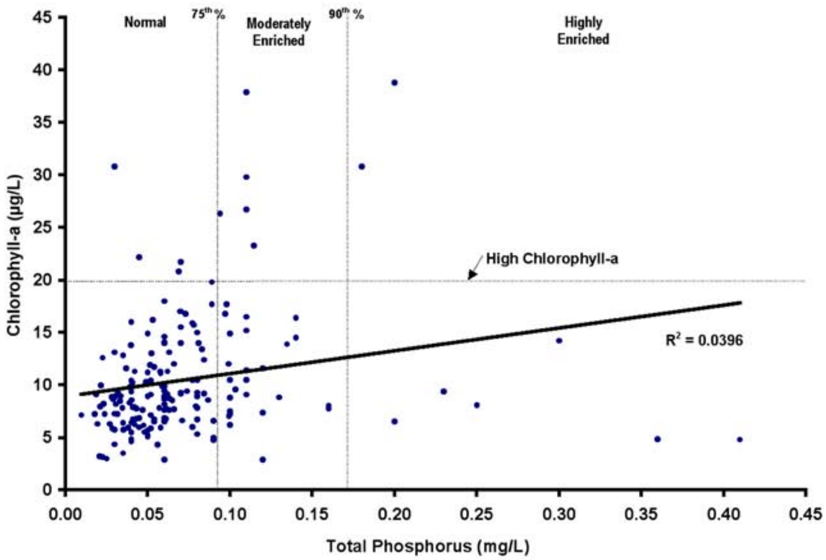
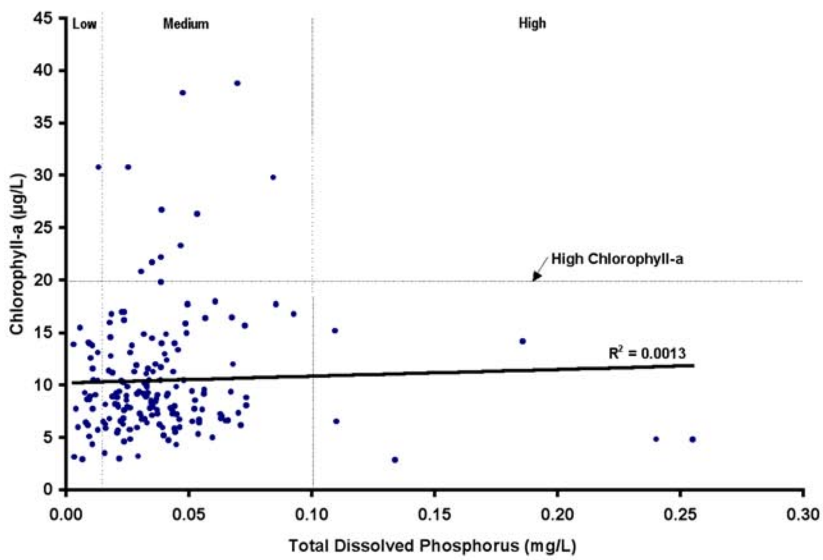


Figure 3.2.7. Summary of nitrogen measures versus chlorophyll-a measures collected from SCECAP sites. The top figure shows total nitrogen (TN) on the x-axis, the middle graph shows total dissolved nitrogen (TDN) on the x-axis, and the bottom graph shows dissolved inorganic nitrogen (DIN) on the x-axis. The vertical dotted lines on the top graph show threshold criteria used by SCECAP to represent normal, moderately enriched, and highly enriched TN conditions (see report text), the middle graph shows NOAA criteria (Bricker et al., 1999) for low, medium and high TDN, and the bottom graph shows USEPA (in review) criteria for good, fair and poor DIN conditions. The horizontal dotted line shows the criteria for high chlorophyll-a used by all programs.





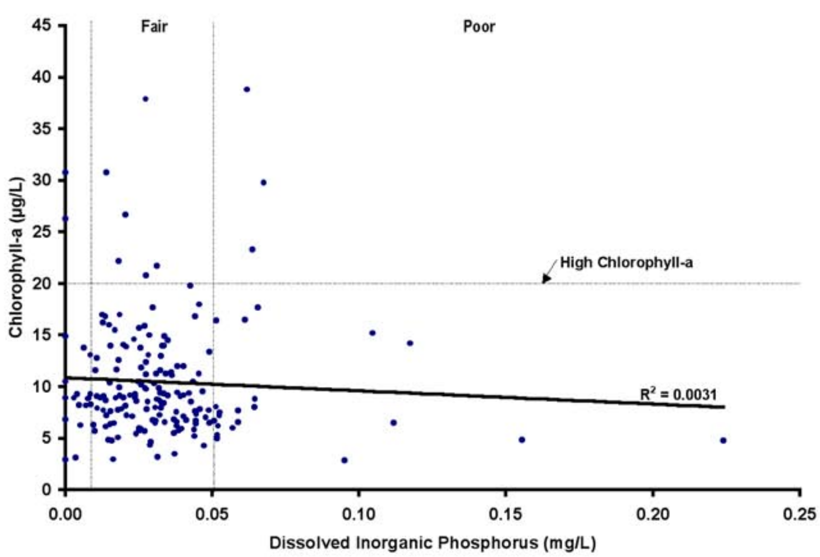


Figure 3.2.8. Summary of phosphorus measures versus chlorophyll-a measures collected from SCECAP sites. The top figure shows total phosphorus (TP) on the x-axis, the middle graph shows total dissolved phosphorus (TDP) on the x-axis, and the bottom graph shows dissolved inorganic phosphorus (DIP) on the x-axis. The vertical dotted lines on the top graph show threshold criteria used by SCECAP to represent normal, moderately enriched, and highly enriched TP conditions (see report text), the middle graph shows NOAA criteria (Bricker et al., 1999) for low, medium and high TDP, and the bottom graph shows USEPA (in review) criteria for good, fair and poor DIP conditions. The horizontal dotted line shows the criteria for high chlorophyll-a used by all programs.

the samples with high chlorophyll-a concentrations had concentrations > 0.8 mg/L for TDN and 0.9 for TDP (Figures 3.2.7, 3.2.8). These values are below the thresholds identified by NOAA as indicative of high nutrient concentrations that may result in algal blooms (Bricker *et al*., 1999).

Similarly, comparisons of DIN and DIP versus chlorophyll-a concentrations were also not correlated. The USEPA (in review) has developed criteria for these nutrients that correspond to good, fair, or poor levels of DIN and DIP. Using their criteria, only one of the sites sampled in 2000-2002 had poor (high) DIN concentrations and that site had a relatively low chlorophyll-a concentration. SCECAP sites with high chlorophyll-a concentrations always had DIN concentrations ≤ 0.1 mg/L. In contrast, a high percentage of the SCECAP sites sampled in 2000-2002 had DIP concentrations considered to be poor by the USEPA. Only three of these sites also had chlorophyll-a concentrations the USEPA considers to be high. Rather, most of the SCECAP sites with high chlorophyll-a concentrations had DIP values < 0.03 mg/L. Thus, the USEPA criteria for DIN and DIP do not appear to be effective indicators of high phytoplankton concentrations indicating possible eutrophication.

Biochemical Oxygen Demand

The five-day Biochemical Oxygen Demand (BOD_5) is a measure of the amount of oxygen consumed by the decomposition of carbonaceous and nitrogenous matter, both natural and man-made wastes, in the water column. Although BOD_5 is regulated by National Pollutant Discharge Elimination System (NPDES) permits to protect instream dissolved oxygen concentrations, there are no freshwater or saltwater standards for natural waters. Both the SCDHEC water quality monitoring program and the SCECAP program include measurements of BOD_5 in order to obtain information on areas where unusually high values may occur, but BOD_5 has been dropped from the integrated measure of water quality since there are no clear guidelines or state criteria applicable for saltwater habitats. Based on historical SCDHEC data (1998a), BOD_5 values > 2.6 mg/L are considered to be very high since they represent the upper 90th percentile of the historical observations. Values > 1.8 and ≤ 2.6 are considered to be moderately high since they are above the 75th percentile of historical records but below the 90th percentile, and values ≤ 1.8 mg/L are considered to be normal.

Average BOD_5 concentrations found at creek sites sampled in 2001-2002 were 0.6 mg/L and the average at open water sites was 0.4 mg/L (Figure 3.2.9), which was much lower than the average values observed in the 1999-2000 survey (Van Dolah *et al*., 2002a, c). As in the 1999-2000 survey, this difference was not statistically significant ($p = 0.5$); only a slightly higher percentage of the state's creek habitat had elevated BOD_5 levels that exceeded the 75th and 90th percentiles of historical detectable observations when compared to open water habitat (Figure 3.2.9, data online). High BOD_5 concentrations may be indicative of poor water quality.

Water Column Total Organic Carbon

Total organic carbon (TOC) represents another indicator of biological productivity. It reflects the products of organic decomposition and amount of detritus in the water column. There are no state standards for TOC, but values greater than 11 mg/L exceed the 75th percentile of historical data collected in the state's coastal zone from 1993-1997 (SCDHEC, 1998a). Therefore, values > 11 mg/L are considered to be moderately high for SCECAP samples. Values greater than 16 mg/L exceed the 90th percentile of the historical database and are considered to be very high for SCECAP samples.

Average TOC concentrations observed during 2001-2002 were 5.4 mg/L at the creek sites and 5.3 mg/L at the open water sites (Figure 3.2.10, data online). Only 3% of the creek habitat and 5% of the open water habitat had concentrations that exceeded the 75th percentile of historical observations. None exceeded the 90th percentile concentration.

Due to the consistently low TOC values observed at the sites sampled during both the 1999-2000 and 2001-2002 surveys of this program, TOC measurements are not included in the integrated measure of overall water quality.

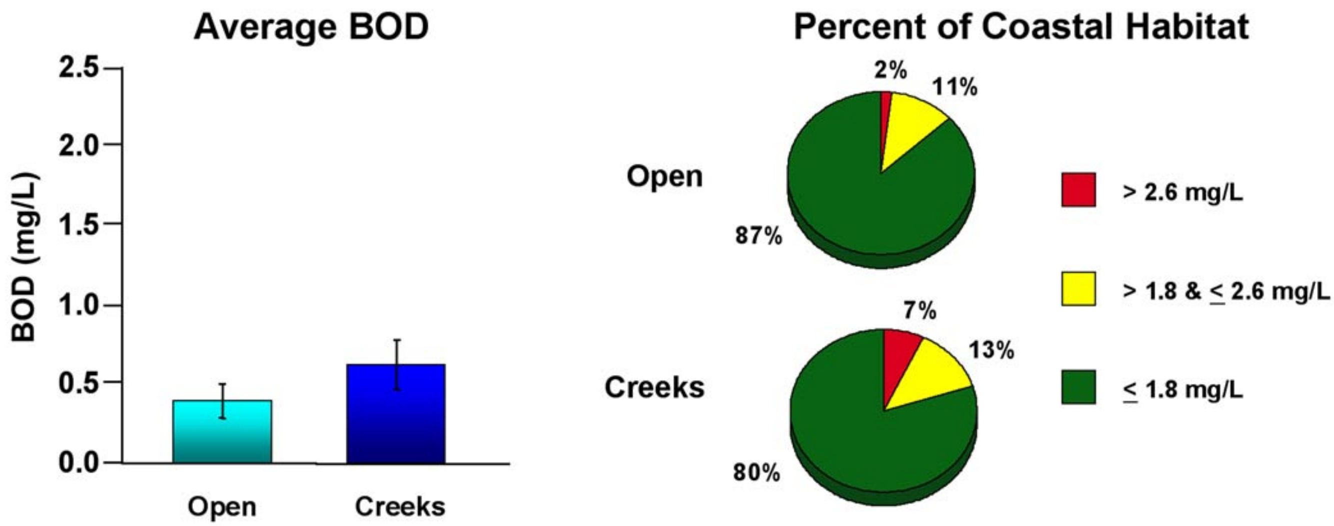


Figure 3.2.9. Comparison of the average five-day biochemical oxygen demand (BOD_5) concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various BOD_5 ranges that represent normal (green), moderately high (yellow) and very high (red) relative to SCDHEC historical data.

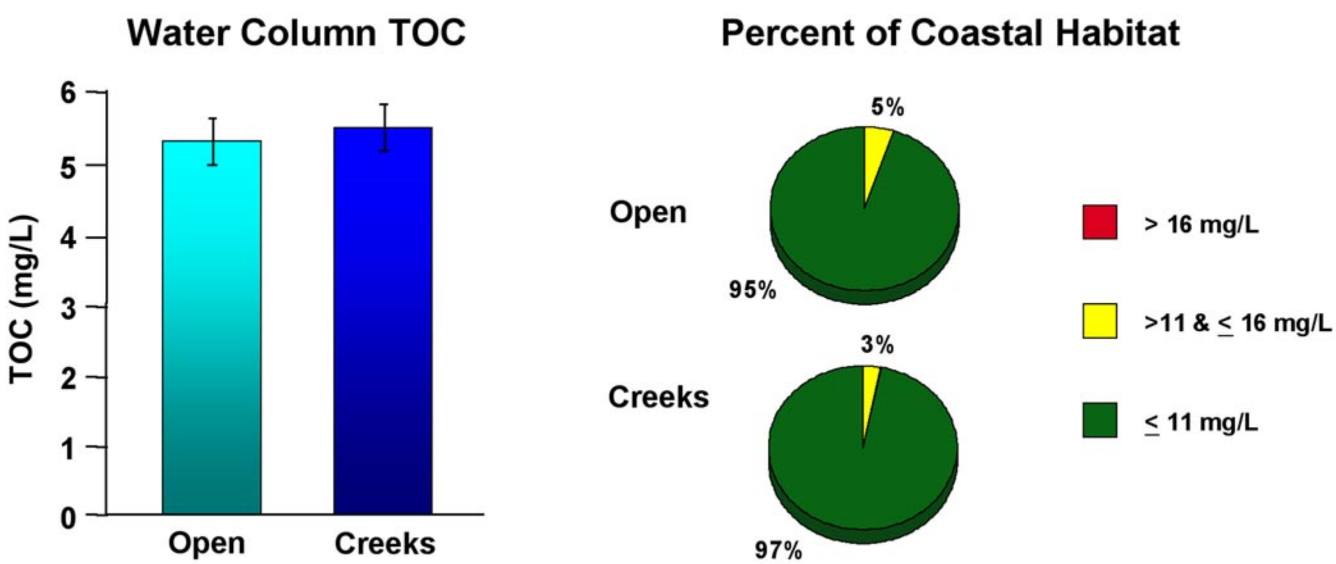


Figure 3.2.10. Comparison of the average total organic carbon (TOC) concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various TOC ranges that represent normal (green), moderatly high (yellow) or very high (red) values relative to SCDHEC historical data.

Fecal Coliform Bacteria

Coliform bacteria are present in the digestive tracts and feces of all warm-blooded animals and public health studies have established correlations between adverse human health effects and the concentration of fecal coliform bacteria in recreational, drinking, and shellfish harvesting waters. State fecal coliform standards to protect primary contact recreation requires a geometric mean count that does not exceed 200 colonies/100 mL based on five consecutive samples in a 30 day period and no more than 10% of the samples can exceed 400 colonies/100 mL. Fecal coliform criteria established by the SCDHEC for "Shellfish Harvesting Waters" (SFH) to protect for shellfish consumption requires that the geometric mean shall not exceed 14 colonies/100 mL and no more than 10% of the samples can exceed 43 colonies/100 mL (SCDHEC, 2001b). Since only a single fecal coliform count was collected at each site, compliance with the standards cannot be strictly determined, but the data can provide some indication of whether the water body is likely to meet standards. Although not all of the waters sampled are classified as "Shellfish Harvesting Waters," for SCECAP, we consider any sample with > 43 colonies/100 mL to represent fair conditions (i.e., potentially not supporting shellfish harvesting) and any sample with > 400 colonies/100 mL to represent poor conditions (i.e., potentially not supporting primary contact recreation).

The average of fecal coliform measurements obtained during the 2001-2002 statewide assessments were 30.4 colonies/100 mL in the creeks and 13.3 colonies/100 mL at open water sites (Figure 3.2.11). This difference was statistically significant ($p = 0.01$). The higher average for the tidal creek sites was largely due to the presence of $\geq$ 300 colonies/100 mL at two sites (RT01628, RT022021). Using the SCECAP criteria and CDF analyses, approximately 73% of the state's creek habitat was good, 24% was fair, and 3% was poor with respect to fecal coliform concentrations. Approximately 83% of the state's open water habitat had good fecal coliform levels, 17% had moderately high fecal coliform concentrations, and no sites had coliform colony counts > 400 (data online). The higher fecal coliform counts observed in creek habitats is most likely due to the proximity of these small drainage systems to upland runoff of both human and domestic wastes as well as wildlife sources, combined with the lower dilution capacity of creeks compared to larger water bodies. Greater protection of tidal creek habitats is warranted in areas where upland sources of waste can be identified and controlled.

Turbidity

Measures of water clarity provide an indication of the amount of suspended particulate matter in the water column. South Carolina's estuarine waters are naturally turbid compared to many other states. Exceptionally high turbidity levels may be harmful to marine life. SCDHEC has recently developed a maximum saltwater state standard for turbidity of 25 NTU. This corresponds to the 90th percentile of the SCDHEC saltwater database, which was obtained primarily from the larger estuarine water bodies. Therefore, values above 25 NTU are considered to be poor for this program. The 75th percentile, representing partially elevated levels, is 15 NTU. Values > 15 NTU and $\leq$ 25 NTU are considered to be fair for SCECAP samples.

Average turbidities measured in the 2001-2002 survey by this program were 21 NTU in the tidal

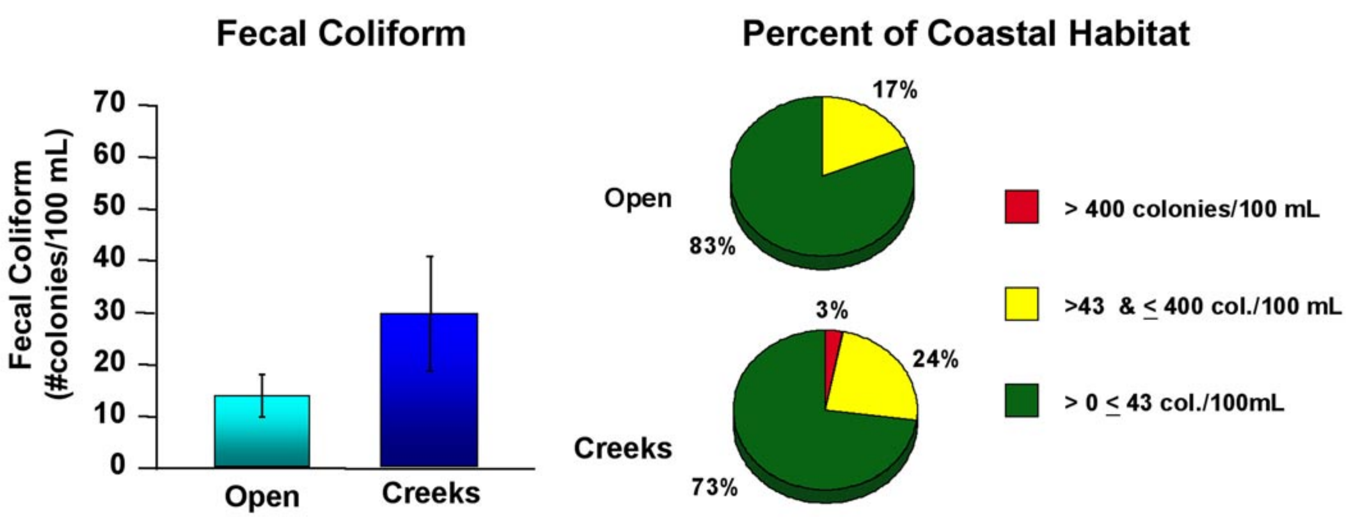


Figure 3.2.11. Comparison of the average fecal coliform concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various concentrations that are normal (green), moderately high (yellow) and indicative of possible unsuitability for shellfish harvest, or very high (red) and indicative of possible unsuitability for primary contact recreation.

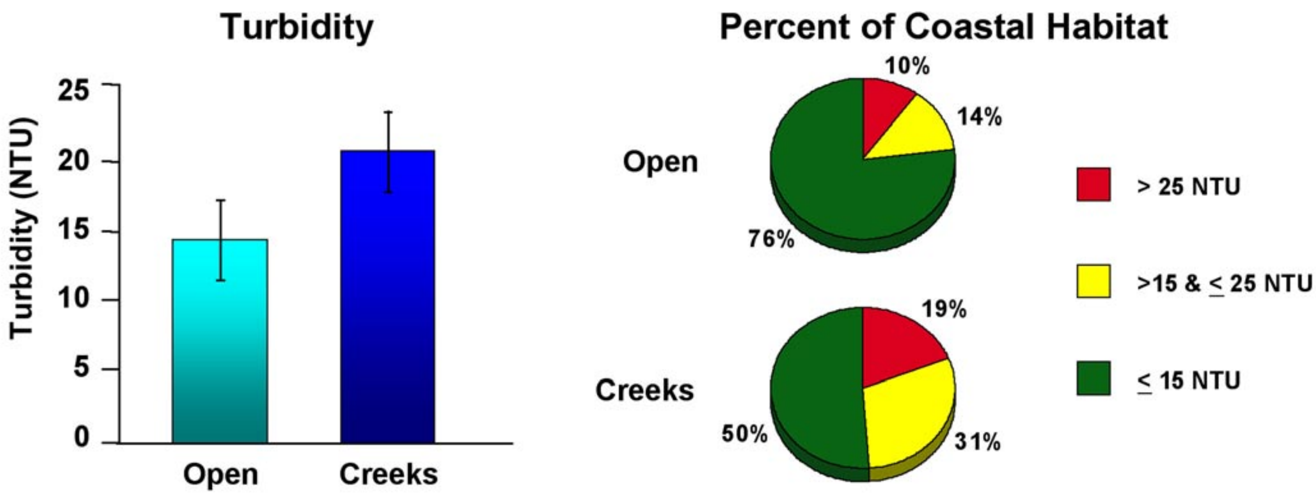


Figure 3.2.12. Comparison of the average turbidity concentrations observed in tidal creek and open water habitats during 2001-2002, and estimates of the percent of the state's coastal habitat representing various turbidity ranges that represent good (green), fair (yellow) or poor (red) values relative to SCDHEC historical data and state standards.

creeks and 15 NTU in the open water habitat (Figure 3.2.12; data online), which is almost identical to the averages observed in the 1999-2000 survey (Van Dolah *et al*., 2002a). The difference between habitats was statistically significant ($p = 0.002$). Based on the single measure of turbidity taken at each station, approximately 19% of the tidal creek habitat exceeded the State standard, whereas only 10% of the open water habitat exceeded the standard (Figure 3.2.12, data online). As noted by Van Dolah *et al.* (2002a, c), turbidity levels in tidal creeks may be naturally higher due to the shallow depths of these systems (i.e., surface samples are often within 1-2 m of the bottom) combined with re-suspension of the bottom sediments due to tidal currents.

Alkalinity

Alkalinity measurements were collected by SCECAP to be consistent with SCDHEC's larger water quality monitoring program. There are no state standards for alkalinity in saltwater and research is lacking on how high or low alkalinity values affect estuarine biota. Until there is better information on how alkalinity should be interpreted, the data are only summarized at the SCECAP web site.

Integrated Assessment of Water Quality

SCECAP has developed an integrated measure of water quality using multiple parameters combined into a single index value. Six parameters were used to develop the index of water quality for the 1999-2000 survey: dissolved oxygen (DO), biochemical oxygen demand (BOD_5), fecal coliform bacteria, total nitrogen (TN), total phosphorus (TP), and pH. For the 2001-2002 survey, BOD_5 was dropped from the index because there are no documented criteria or guidelines for BOD_5 in estuarine waters and the effects of BOD_5 in these systems are unknown. Chlorophyll-a was added to the index as a measure of phytoplankton response to nutrient concentrations.

Dissolved oxygen (DO) provides an indication of oxygen availability, which can become too low to sustain aquatic organisms, especially during the summer. Total nitrogen and phosphorus provide measures of nutrient concentrations. When combined with chlorophyll-a concentrations, these three parameters provide evidence of whether nutrient enrichment (eutrophication) may be occurring. Fecal coliform concentrations provide an indication of the suitability of the water for shellfish harvesting and primary contact recreation. Measures of pH can indicate whether waters are stressful for many marine species.

Each water quality variable is given a score of 1, 3, or 5. A score of 1 (coded as red) indicates an exceedance of state water quality standards, or if no standards exist, an exceedance of the 90th percentile of either a SCDHEC historical database (SCDHEC, 1998a) or the SCECAP database (cholorphyll-a only). A score of 3 (coded as yellow) represents conditions that may be fair since they either exceeded a portion of the water quality standard or the 75th percentile of the SCDHEC or SCECAP historical database. A score of 5 (coded as green) indicates values that did not exceed a state standard, or in the absence of a state standard, the values were below the 75th percentile of the records for that parameter in the historical SCDHEC or SCECAP database.

The integrated water quality score is an average of all six parameter scores (Figure 3.2.13). For SCECAP, an integrated score ≤ 3 represents relatively poor water quality conditions, scores > 3 but ≤ 4 represent fair water quality conditions, and scores > 4 represent good water quality conditions.

Results of the 2001-2002 survey indicated that approximately 73% of the state's creek habitat during this survey period was good, 22% had fair water quality, and 5% of the creek habitat had poor water quality (Figure 3.2.14). In contrast, 88% of the state's open water habitat had good water quality overall, 12% was considered to be only fair in quality, and none of the open water habitat sampled in this survey period had poor water quality. The specific location of creek sites with poor water quality, and the coding of each variable that comprises the integrated water quality score, is provided in Appendix 2.

As noted in the 1999-2000 survey (Van Dolah *et al.*, 2002a), the higher percentage of poor and fair water quality conditions in creeks indicates that

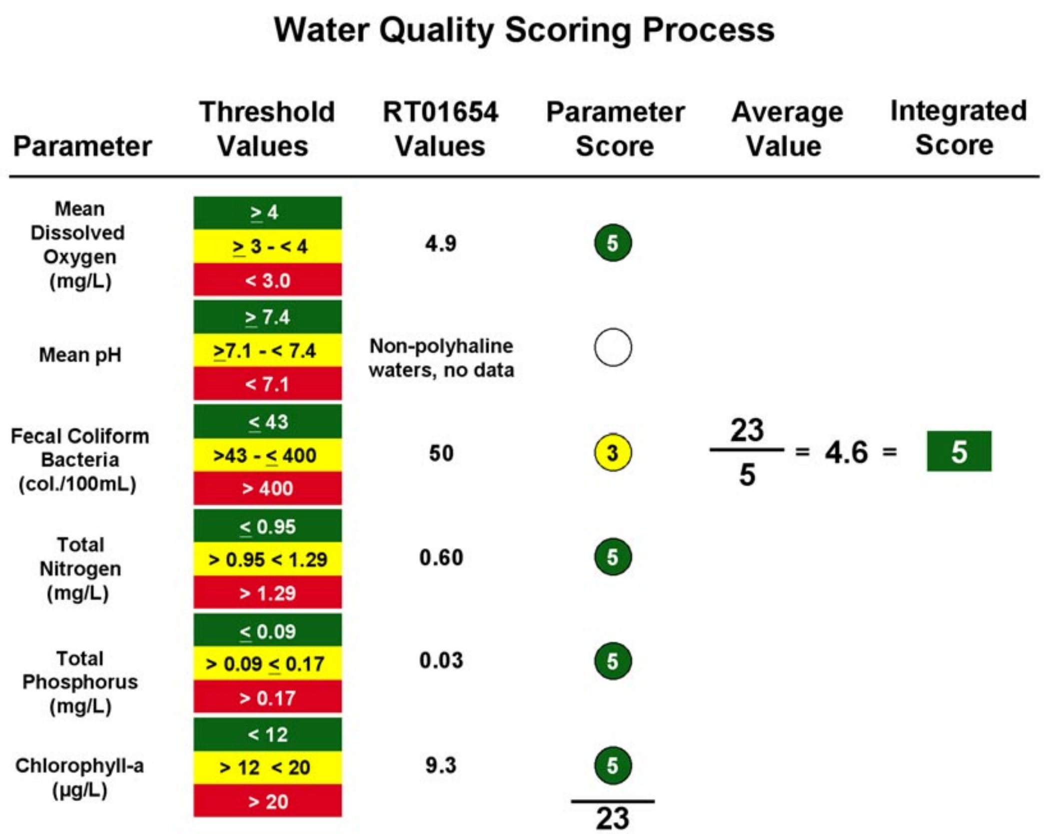


Figure 3.2.13. Summary of water quality threshold values and scoring process used to obtain the integrated water quality score for 2001-2002. Values obtained from station RT01654 were used in this example. Green indicates good water quality measures, yellow indicates values that are considered to be fair relative to state standards or historical data obtained by SCDHEC, and red indicates poor water quality relative to state standards or historical data. An average value > 4.0 represents good overall water quality conditions, and receives an integrated score of 5. An average value > 3.0 but ≤ 4.0 represents fair overall water quality, and receives an integrated score of 3. Average values and scores ≤ 3.0 represent poor water quality for the purposes of SCECAP and receive an integrated score of 1.

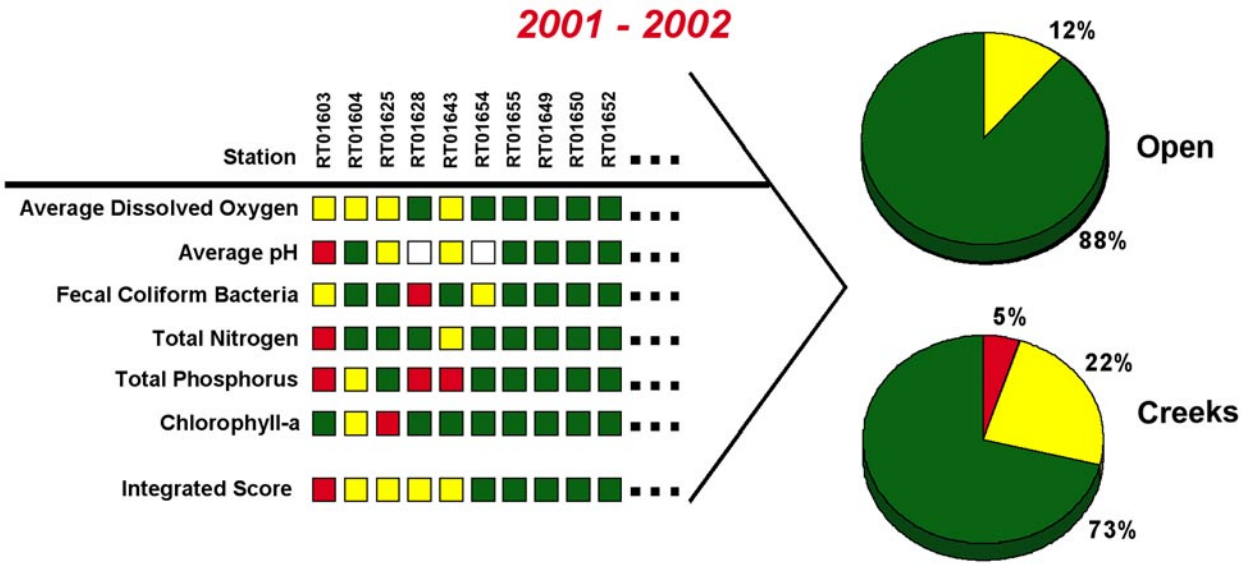


Figure 3.2.14. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated water quality score developed for the SCECAP program. This measure of overall water quality incorporates the six water quality parameters shown.

these habitats are often more stressful environments, especially since many of these sites were in relatively pristine locations. The higher percentage of creek habitat with poor or fair conditions may also, in part, reflect the relatively greater effect of anthropogenic runoff into these smaller water bodies due to their proximity to upland sources and their lower dilution capacity. It may also be the result of using thresholds derived from SCDHEC's historic database, which is composed predominantly of data from open water habitats. Now that four years of data are available SCECAP personnel will review the historical data available for both habitat types to identify whether the threshold criteria for some of the water quality parameters measured in creek habitats should be changed from those used in this report to reflect the greater natural variability in these habitats.

Due to the change in methods and thresholds in assessing overall water quality conditions in South Carolina's estuaries, a re-evaluation of all survey data collected since 1999 was conducted on an annual basis to evaluate whether any trends were observed since the inception of SCECAP. While the probability-based sampling approach is not as suitable for trend analysis compared to fixed stations, it is possible to report changes in condition over time using this approach. In contrast to our two-year data summary periods, the annual assessment combines both the open water habitat and the tidal creek habitat, with appropriate weighting for each habitat type. The reader should note that by using this approach, the condition of tidal creeks contributes much less than the condition of open water habitat since tidal creeks comprise only about 17% of the states estuarine water surveyed by SCECAP (Van Dolah *et al*., 2002a).

Comparison of the state's overall water quality condition on an annual basis indicated very little change over the four-year period (Figure 3.2.15). For all four years, more than 80% of the state estuarine waters rank as good in quality using the SCECAP criteria, and less than 5% of the estuarine waters are considered to be poor in quality. The lack of any major change in condition over time is probably due in part to the fact that all sampling has occurred during a major and unusual drought period. Return of climatic conditions to conditions with higher rainfall, resulting in more upland runoff, may change the water quality estimates considerably. The 2003-2004 survey should be indicative of estuarine water quality conditions during wetter years.

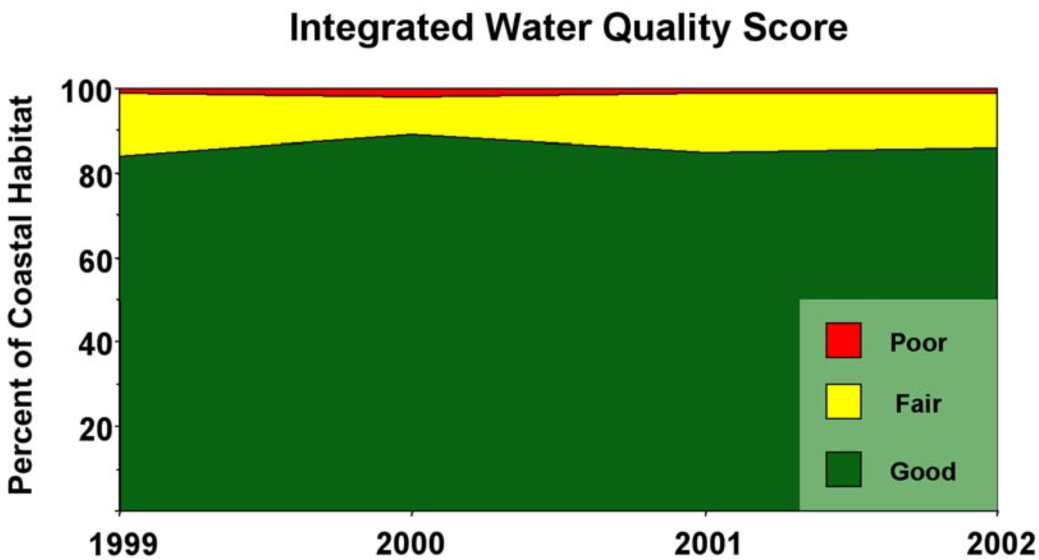


Figure 3.2.15. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated water quality score when tidal creek and open water habitats are combined and compared on an annual basis.

3.3 Sediment Quality

Sediment Composition

The composition and quality of estuarine sediments can affect both the structure of the biotic assemblage as well as the bioavailability of certain contaminants to local biota. Sediments are generally composed of a combination of sand, silt and clay. The composition of the benthic community can vary depending on how sandy or how muddy (silts and clays combined) the sediments are. Also, contaminants tend to adsorb to silt and clay particles so muddy sediments are more likely to have higher contaminant concentrations than sandy sediments.

The average percentage of the silt/clay fraction at open water sites was 22% silt/clay compared to a mean of 30% silt/clay at tidal creek sites (Figure 3.3.1, data online). This difference was statistically significant ($p < 0.015$); however, there was considerable variability in the percent of silt/clay observed among the stations sampled in both habitats (from < 3% to > 95%; data online).

Approximately 6% of the sediments in open water habitat sampled in 2001 – 2002 were composed predominantly of silt/clay (> 80% silt/clay), while 14% of tidal creek habitats were predominantly silt and clay (Figure 3.3.1; data online). Values for mean silt/clay fraction and percent of the state's total habitat representing each sediment type were similar between the two survey periods (1999-2000 and 2001-2002; Van Dolah *et al*., 2002a).

Sediment Total Organic Carbon

Total organic carbon (TOC) provides a measure of how much organic material occurs in sediments. Hyland *et al.* (2000) found that extreme concentrations of TOC can have adverse effects on benthic communities. TOC levels below 0.5 mg/g (0.05%) and above 30 mg/g (3.0%) were related to decreased benthic abundance and biomass.

The TOC of sediments in tidal creeks ranged from 0.1 to 5.7% with a mean of 1.3% (data online). Sediments in open water habitats contained lower concentrations of TOC with a mean of 0.9% and a range of 0.0 to 7.8% (Figure. 3.3.2). The difference between total organic carbon content in tidal creeks and open water sites was statistically significant ($p < 0.004$). Decomposing salt marsh plants and upland runoff are the primary sources of organic carbon. Open water sites are generally farther away from these sources resulting in lower TOC concentrations than tidal creek habitats.

Approximately 15% of the tidal creek habitats had sediment TOC levels that were above 3%, with

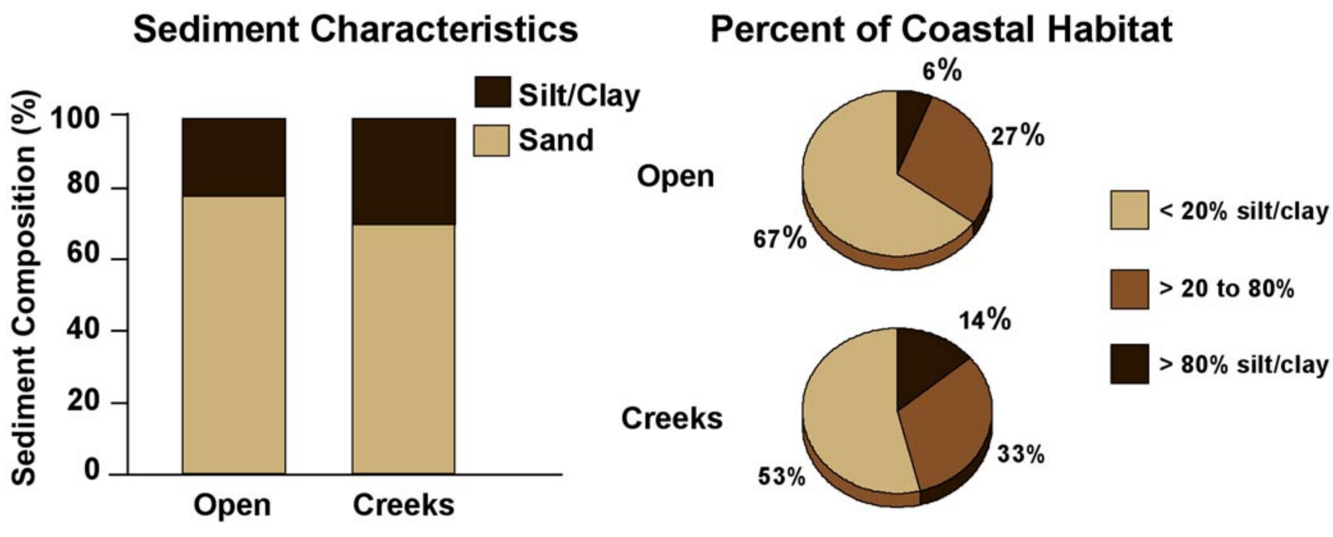


Figure 3.3.1. The average percent of sand versus silt/clay at open water and tidal creek sites sampled in 2001-2002 and estimates of the proportion of the state's coastal habitat that is primarily composed of the silt/clay fraction (> 80% silt/clay), mixed (20-80% silt/clay), or sandy (< 20% silt/clay) sediments.

no tidal creek habitat below 0.05%. About 6% of the open water habitats in the SCECAP survey had TOC levels that were less than 0.05%. Approximately 9% of the area of open water habitat was above 3% (Figure 3.3.2, data online).

The National Coastal Assessment Program (USEPA, in review) has used TOC concentrations of above 2% and above 5% to indicate fair or poor sediment quality, respectively. Using these values, 4% of the tidal creek habitat and 2% of the open water habitat had TOC concentrations equal to or above the 5% threshold indicating poor conditions. Another 20% and 10% of tidal creek and open water respectively were in the fair category (2-5% TOC concentrations).

Porewater Ammonia

Total ammonia as nitrogen (TAN) in sediment porewater is another source of potential toxicity in sediments. The effects of TAN on marine biota are highly variable depending on the species considered (Sims and Moore, 1995; Moore *et al.,* 1997). A value of 14 mg/L and 30 mg/L of TAN were used to indicate potential toxicity to seed clams (Ringwood and Keppler, 1998) and amphipods, respectively.

In the 2001-2002 survey, TAN levels were similar between open water sites (3.04 mg/L) and tidal creek sites (3.08 mg/L), and generally well below levels considered to be toxic (Figure 3.3.3; data online). Only 2% of both the open water and tidal creek habitats had TAN concentrations > 14 mg/L and none of the sites sampled in 2001-2002 had pore water TAN concentrations > 30 mg/L (data online). These values are similar to the 1999-2000 survey (Van Dolah *et al*., 2002a), indicating that there was no detectable change between the two survey periods.

Contaminants

Sediments collected for SCECAP were examined for a wide range of contaminants including 15 metals (thallium was added during the 2001 sampling year), 25 polycyclic aromatic hydrocarbons (PAHs), 30 polychlorinated biphenyls (PCBs), and 23 pesticides. For many of these contaminants, Long *et al.* (1995) published bioeffects guidelines that reflect the concentration of a contaminant that resulted in adverse bioeffects in 10% of the studies examined (defined as Effects Range-Low or ER-L) and concentrations that resulted in adverse effects in 50% of the studies (defined as Effects Range-Median or ER-M).

Eight of the randomly selected open water sites in 2001 and six in 2002 had one or more contaminant concentrations above ER-L values. Nine tidal creek sites in 2001 and eleven in 2002 had one or more contaminant concentrations above ER-L values (data online). Many of the ER-L exceedances in the tidal creeks were due to high levels of arsenic. Arsenic

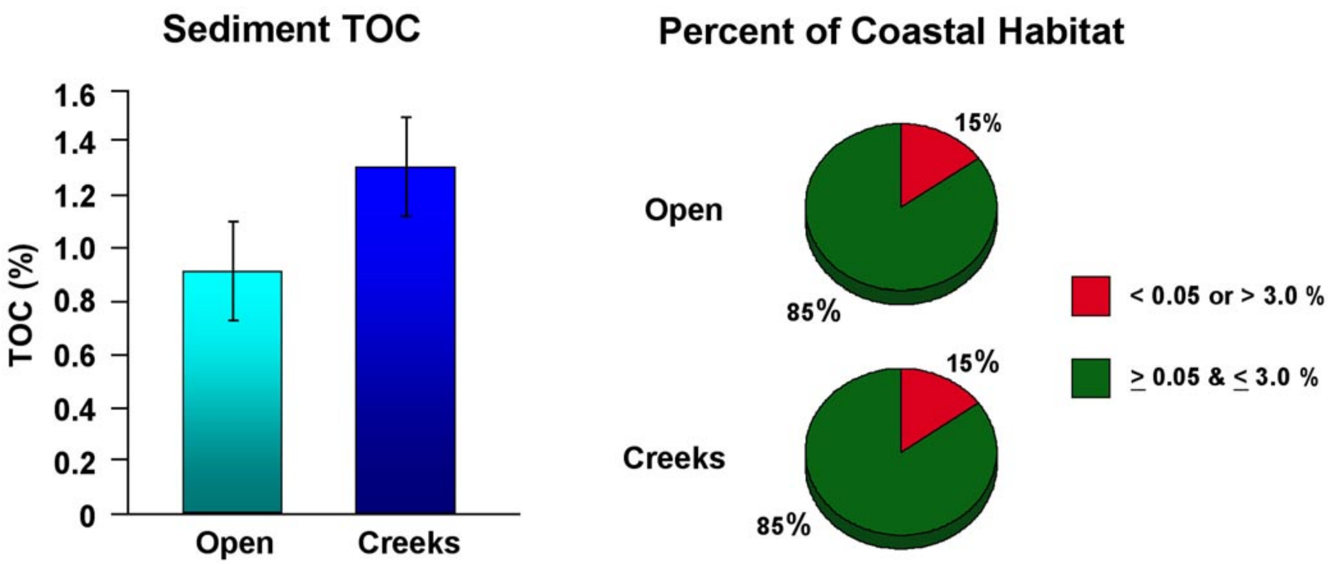


Figure 3.3.2. Average percent total organic carbon (TOC) concentration in sediments at open water and tidal creek sites sampled in 2001-2002 and estimates of the proportion of the state's coastal habitat having TOC levels (< 0.05 or > 3%), which may cause stress in benthic communities.

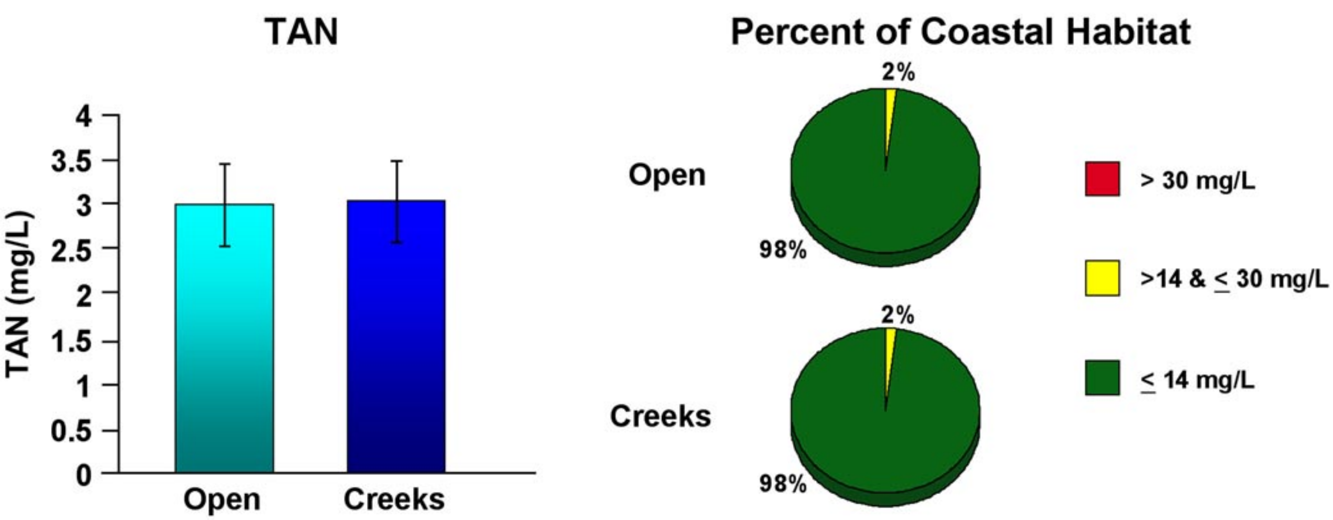


Figure 3.3.3. Average total ammonia nitrogen (TAN) concentration in sediment pore water at open water and tidal creek sites sampled in 2001-2002 and estimates of the proportion of the state's coastal habitat having TAN concentrations that have a high probability of causing stress in benthic communities (> 30mg/L, red), moderate probability of causing stress (> 14 mg/L & ≤ 30 mg/L, yellow), or low probability of causing stress (≤ 14 mg/L, green).

concentrations are naturally elevated in South Carolina estuarine sediments (Scott *et al.*, 1994; 2000; Sanger *et al.,* 1999a) and therefore the values observed are probably not related to anthropogenic stress. Other metal contaminants that exceeded ER-L values include nickel, chromium, mercury, lead, copper, cadmium, and zinc. A few PCBs, PAHs, and pesticides also exceeded their respective ER-L values. In most cases, the stations with ER-L exceedences were located in urbanized estuaries such as Charleston Harbor and Winyah Bay, reflecting the increased loadings of contaminants in these areas. Only one of the randomly selected sites sampled in 2001-2002 by the SCECAP program had contaminant concentrations that exceeded ER-M values. This station (RO026010) was located in Winyah Bay and had zinc levels of 628 µg/g (ER-M value for zinc is 410 µg/g). The contaminant concentrations found in the randomly located stations sampled during the 2001-2002 survey are similar to those found in the 1999-2000 survey.

Among the seven non-random stations in 2001-2002, two stations had contaminant levels that exceeded their respective ER-M values, in addition to having seven to eight ER-L exceedances. At station NO01098 in the Ashley River, ER-M values were exceeded for copper and zinc. Six other metals and two PAH analytes exceeded ER-L concentrations at this site (data online), which is located adjacent to the Columbia Nitrogen Plant and the Koppers Plant. Both of these plants are EPA Superfund (CERCLA) sites. At Station NT01599 (Brickyard Creek in the Ashley River), Total DDT levels of 49.4 ng/g slightly exceeded the ER-M value for Total DDT of 46.1 ng/g. This station also had ER-L exceedances for seven metals and one other pesticide (data online). This station is in a tidal creek that drains a heavily industrialized area of the Charleston peninsula.

While individual contaminants were elevated at some sites, a better assessment of overall contaminant exposure may be derived from the combined concentrations of all contaminants present at a site relative to bioeffects guidelines. Dividing the measured concentration of 24 contaminants by their respective ER-M values, and taking the average of all 24 values creates a combined value. The ERM-Quotient (ERM-Q) has been evaluated by Hyland *et al.* (1999) at more than 230 estuarine sites throughout the southeast, and provides a method for predicting stress in benthic invertebrate communities. ERM-Q values ≤ 0.02 represent a low risk of observing degraded benthic communities, values > 0.02 and ≤ 0.058 represent a moderate risk, and values > 0.058 represent a high risk of observing degraded benthic communities.

The mean ERM-Q among open water stations was 0.016 with a range of 0.001 to 0.122 (Figure 3.3.4; data online). The mean ERM-Q among tidal creek stations was 0.016 with a range of 0.001 to 0.046. Mean ERM-Q between habitat types was not significantly different. Using the criteria developed by Hyland *et al.* (1999), 21 of the tidal creek stations sampled (9 in 2001 and 12 in 2002) had ERM-Q values indicative of a moderate risk to benthic assemblages while the remainder had ERM-Q values indicative of a healthy benthos. Thirteen open water stations had ERM-Q values representing a moderate risk to benthos (6 in 2001 and 7 in 2002). Additionally, two stations sampled in 2002 had ERM-Q values indicative of high risk to benthic health (ERM-Q $>$ 0.058). These stations were located in the Cooper River across from the old Navy Base (RO026090) and in the Ashley River, just below the Koppers Superfund site (RO026030) (data online).

The estimated percent of the state's tidal creek habitat that had ERM-Q values indicative of moderate risk to benthic health was 24% compared to 17% of the open water habitat. None of the state's tidal creek habitat had a high ERM-Q, and only 3% of the state's open water habitat had a high ERM-Q value (Figure 3.3.4). These results are similar to the 1999-2000 survey. A year-by-year comparison of percent of total habitat (creek and open water habitats combined) shows some minor variation in the percentage of habitat that falls in the poor or fair categories, but no major increasing or decreasing trend in the proportion of South Carolina estuarine habitat with poor or fair contaminant levels (Figure 3.3.5). However, the 1999-2002 period coincided with a 4-5 year drought. Some contaminant concentrations may, in periods of normal rainfall, increase as runoff from the land increases.

Toxicity

Even if estuarine sediments have levels of contaminants shown to cause adverse effects or mortality in laboratory exposure studies, these contaminants may not be bioavailable to organisms living in and around the sediments due to chemical binding properties with some sediments. Laboratory bioassays are used as indicators of contaminant bioavailability. The three bioassays used for the SCECAP survey provide useful evidence of probable contaminant effects on benthic species, particularly when two or more of the assays show toxicity.

A weight of evidence approach is used to define sediment toxicity. Positive tests in two or more of the assays indicate a high probability of toxic sediments, only one positive test indicates possible evidence of

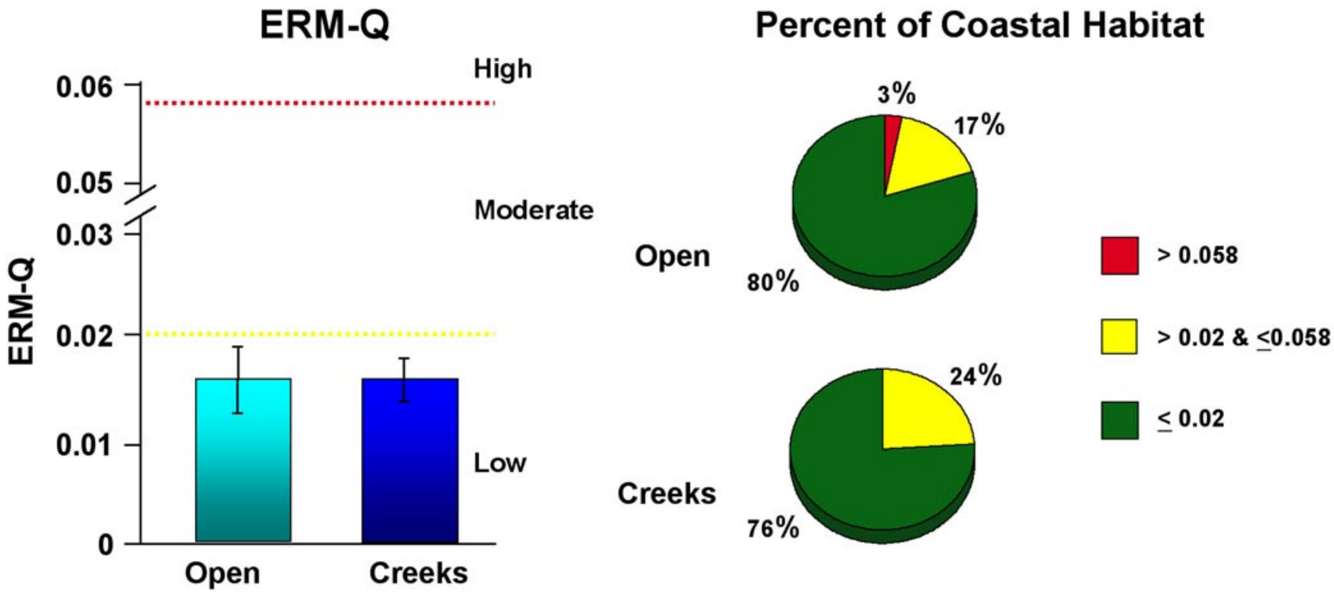


Figure 3.3.4. Mean Effects Range-Median Quotient (ERM-Q) value representing the combined contaminant concentration at open water and tidal creek sites sampled in 2001-2002 and estimates of the proportion of the state's coastal habitat having ERM-Q values representing a low (< 0.02, green), moderate (> 0.02 - < 0.058, yellow), and high (> 0.058, red) risk of observing stress in benthic communities.

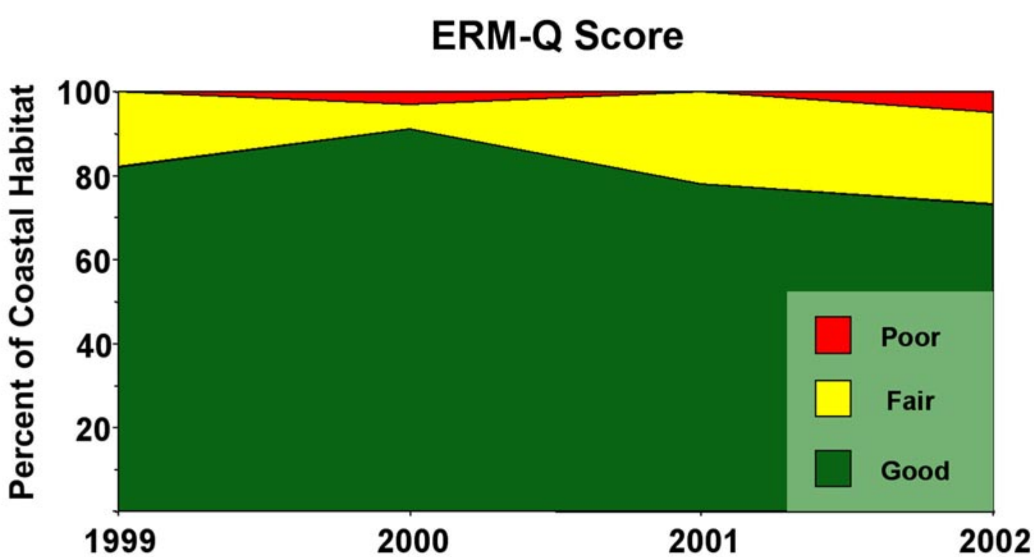


Figure 3.3.5. Mean Effects Range-Median Quotient (ERM-Q) value for all randomly sampled sites from 1999-2002 (tidal creek and open water habitats combined) and estimates of the proportion of the state's coastal habitat having ERM-Q values representing a low (< 0.02, green), moderate (> 0.02 - < 0.058, yellow), and high (> 0.058, red) risk of observing stress in benthic communities.

toxic sediments, and no positive tests indicates non-toxic sediments. For the 2001-2002 survey, 18% of both the tidal creek and open water habitats were considered toxic, and 35% of open water habitats and 55% of tidal creek habitats were considered possibly toxic (Figure 3.3.6). When compared to the 1999-2000 survey (Van Dolah *et al*., 2002a), there was a substantial increase in the area of tidal creek habitat considered toxic or possibly toxic (7% in 1999-2000 and 18% in 2001-2002). However, due to the high

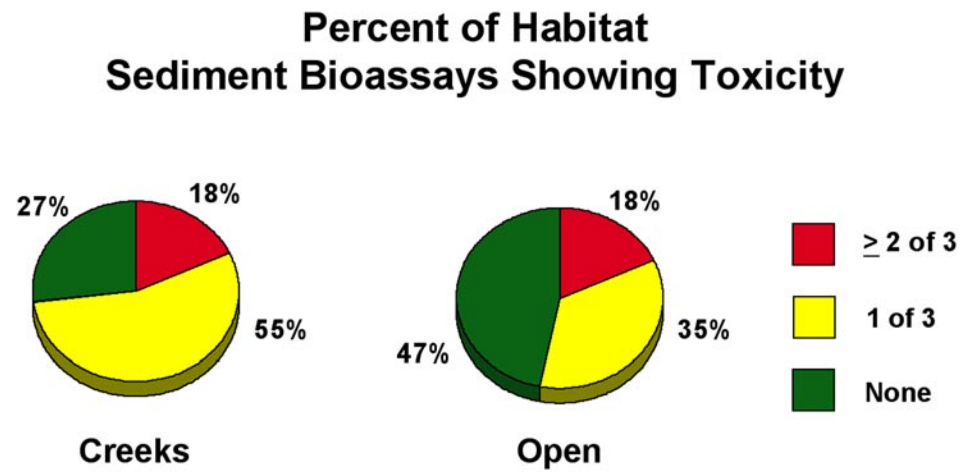


Figure 3.3.6. Summary of sediment bioassay results for 2001-2002 using multiple assays. Sediments are not considered to be toxic if no significant toxicity was observed in any of the tests (green), possibly toxic if one of the tests showed positive results (yellow), and toxic if two or more of the tests showed positive results (red).

variability of the data, this difference is not statistically significant. Thirteen of the 25 sites (52%) sampled in 2001-2002 that had positive toxicity in both assays also had ERM-Q values > 0.02, which represents a moderate to high risk of observing stress in benthic communities. Toxicity in the sites with lower ERM-Q values may reflect toxicity from contaminants with no bioeffects guidelines, or it may represent a "false positive" test result.

Integrated Assessment of Sediment Quality

The integrated sediment quality index combines measures of sediment contaminant concentrations (ERM-Q) and sediment toxicity. For SCECAP, an integrated score < 2 represents relatively poor sediment quality conditions, scores ≥ 2 but < 4 represent fair sediment quality conditions, and scores ≥ 4 represent good sediment quality conditions (Figure 3.3.7). The results of the 2001-2002 survey are similar to the 1999-2000 survey. For 2001-2002, none of the tidal creek habitat had poor overall sediment quality and 40% coded as only fair in overall quality (Figure 3.3.8). In comparison, in 1999-2000, none of the tidal creek habitat coded as poor, and 38% coded as fair in quality. For open water habitats, 2% of the habitat was considered to have poor overall quality, and 28% coded as having only fair sediment quality (values for 1999-2000 were 3% and 30%, respectively).

Annual comparisons, combining both habitat types, show an increasing area of habitat that was considered to be fair from 1999 to 2002, but little change in the proportion of habitat considered to be poor (Figure 3.3.9). The 1999 evaluation showed that none of the estuarine habitat was considered poor and 15% of the habitat was fair. The 2002 evaluation shows 3% of the estuarine habitat was considered poor and 27% was fair, an overall increase of 15% of the habitat falling into the poor or fair categories. While the current trend is statistically non-significant, as the data from the 2003 and 2004 sampling seasons becomes available, this trend can be re-evaluated.

3.4 Biological Condition

Phytoplankton

One of the goals of SCECAP is to utilize several measures of biotic condition to evaluate estuarine habitat quality. Phytoplankton form the base of the food chain and show rapid response to changes in nutrient concentrations and other environmental factors. In addition to measures of total phytoplankton concentration using chlorophyll *a* (see water quality section), the composition of phytoplankton species can be useful for identifying trends in the relative abundance of desirable vs. undesirable species. By "desirable," we refer to species that tend to efficiently support productive food webs, particularly with respect to fish and shellfish populations. By "undesirable," we refer to species that provide inefficient support of food webs and/or cause harm to fish and shellfish. However, the use of phytoplankton

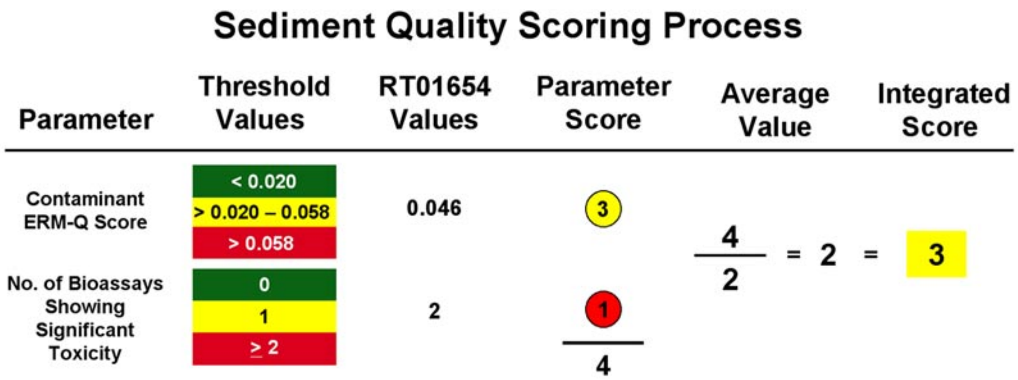


Figure 3.3.7. Summary of sediment quality threshold values and scoring process used to obtain the integrated sediment quality score. Values obtained from station RT01654 were used in this example. Green indicates good sediment quality measures, yellow indicates fair quality that may have some adverse effects on bottom dwelling organisms, and red indicates poor sediment quality with a high probability of adverse bioeffects. For the purposes of SCECAP, an average sediment quality value ≥ 4.0 represents good sediment quality and receives an integrated score of 5. An average value < 4.0 represents fair overall sediment quality and receives a score of 3. An average value < 2.0 represents poor sediment quality and receives an integrated score of 1.

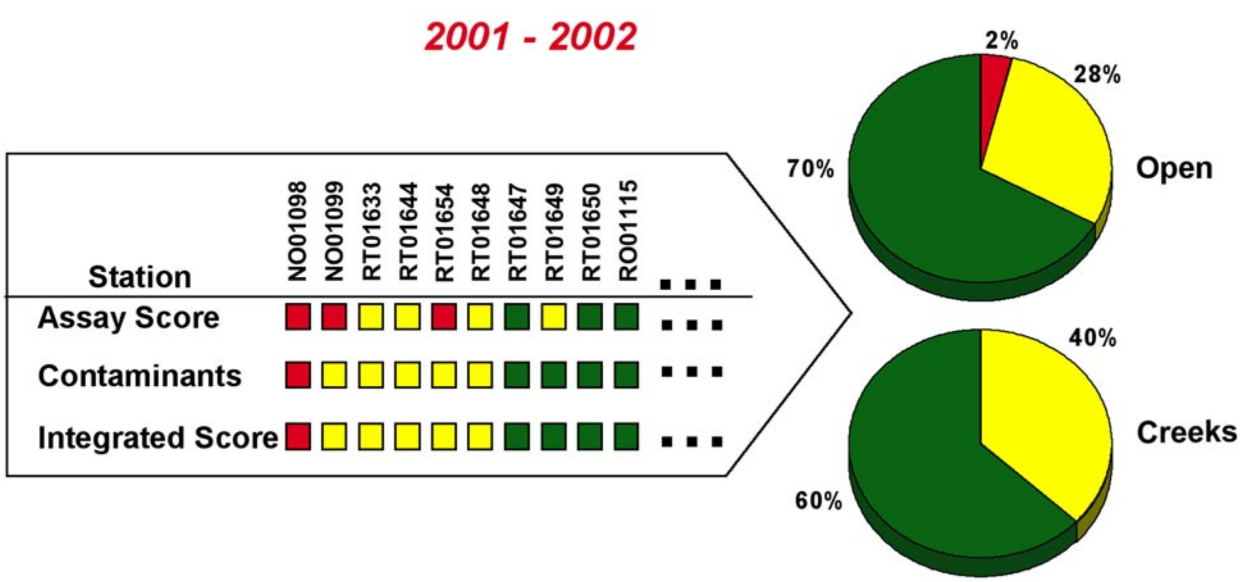


Figure 3.3.8. The proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red), using the integrated sediment quality score developed for SCECAP. This measure of overall sediment quality incorporates the concentration of 24 contaminants relative to known bioeffects levels, and the number of bioassays showing toxicity.

composition data as criteria for biotic condition must be considered in light of the following qualifiers:

a) Almost all phytoplankton communities contain a mixture of species that includes "desirable" and "undesirable" forms. It is the relative proportion of these types that can influence whether ecosystems function efficiently. This proportion can vary seasonally. For example, in North Inlet, a pristine high salinity salt marsh estuary, "desirable" species such as diatoms (Table 3.4.1) make up ~50% of phytoplankton biomass in the summer, but up to ~80% in other seasons (Lewitus *et al*., 1998). This proportion can also change rapidly; for example, monospecific blooms can form and dissipate within days after a nutrient loading event (Lewitus *et al*., 2001).

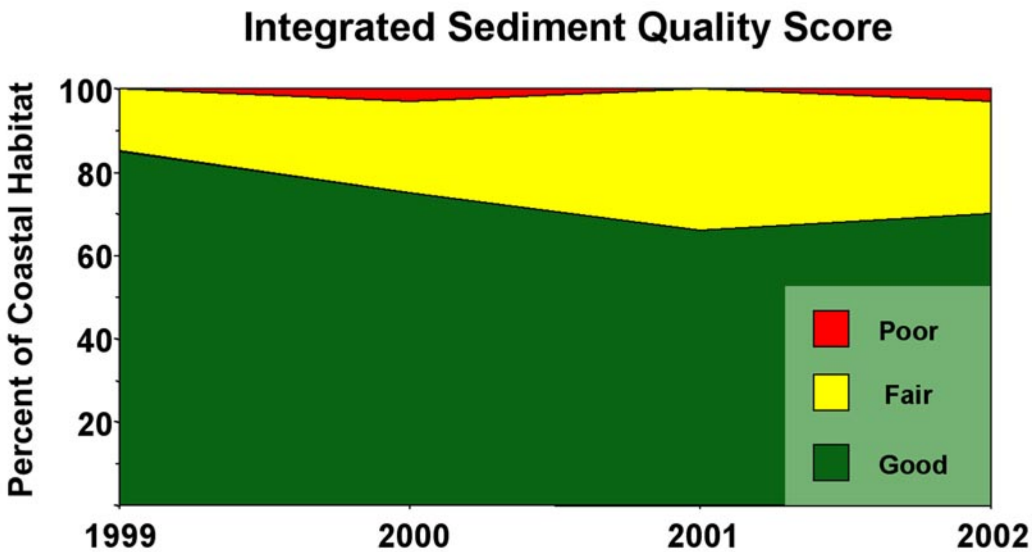


Figure 3.3.9. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated sediment quality score when tidal creek and open water habitats are combined and compared on an annual basis.

b) Categorization of phytoplankton taxa as "desirable" or "undesirable" is an overgeneralization because a given taxonomic group can contain species ranging in desirability. For instance, not all dinoflagellates or cyanobacteria are potentially toxic, and some species may even support productive food webs.

c) These data have greatest value in long-term comparisons where statistically significant changes in the relative proportions of "undesirable" to "desirable" groups are revealed. For example, a decrease in the relative contribution of diatoms to overall phytoplankton composition may be symptomatic of degradation in ecosystem function, especially if correlated with reduced water quality. These data also have value for identifying potential areas where anomalously high proportions of so-called "harmful taxa" (Table 3.4.1) occur. The association of these occurrences with environmental variables and other biotic indices may have predictive value in assessing potential for harmful algal bloom events.

An analytical method, CHEMTAX, is a matrix factorization program that is used to derive phytoplankton community taxonomic structure using pigment data (Mackey *et al*., 1996). Although not as taxonomically precise as microscopy, calculations based on pigment concentrations have been shown to provide useful taxonomic information while allowing large numbers of samples to be processed quickly (Millie *et al*., 1993; Wright *et al*., 1996). A pigment matrix was developed that includes 12 taxonomic groups (Table 3.4.1). In all but one of these groups, the matrix was calibrated using estuarine phytoplankton isolates, improving application to estuarine systems (Mackey *et al*., 1996; Lewitus *et al*., in review). Estuarine representatives of prasinoxanthin-containing prasinophytes were not available to the project. Therefore, Prasinophyceae-B was based on Mackey et al.'s (1996) Prasinophyceae Type 2.

In order to derive a baseline for future comparisons based on the rationale that species in some groups may be more symptomatic of degraded water quality than others, we used the following categories:

1) "*Diatoms*" alone, which generally dominate pristine SC estuarine waters and support efficient and productive food webs (Lewitus *et al.,* 1998);

2) "*Mixed Flagellates*" that are not categorically considered harmful in the sense of producing toxins or otherwise adversely affecting fauna, but that are associated with microbial food webs that less efficiently transfer material and energy to higher trophic levels;

Group	Class	Species	Mean % of Total Biomass in all Samples
Diatom & Dinophyceae-A	Bacillariophyceae	*Thalassiosira* cf. *miniscula*	43%
	Bacillariophyceae	*Cylindrotheca closterium*	
	Bacillariophyceae	*Nitzschia* sp.	
	Dinophyceae-A	*Kryptoperidinium foliaceum*	
Dinophyceae-B	Dinophyceae-B	*Amphidinium carterae*	3.60%
	Dinophyceae-B	*Prorocentrum minimum*	
Cyanophyceae	Cyanobacteria	filamentous species (undes. strain)	5.50%
	Cyanobacteria	*Limnothrix* sp.	
	Cyanobacteria	*Anabaenopsis elekenii*	
	Cyanobacteria	*Synechococcus* sp.	
Raphidophyceae-A	Raphidophyceae-A	*Heterosigma akashiwo*	12%
Prasinophyceae-A	Prasinophyceae-A	*Pyramimonas* sp.	3.10%
Prasinophyceae-B	Prasinophyceae-B	Mackey Prasinophyceae Type 2	13%
	Chlorophyceae	unknown species (undes. strain)	1.30%
Chlorophyceae	Chlorophyceae	unknown species (undes. strain)	
	Conjugatophyceae	*Ankistrodesmus* sp.	
	Chlorophyceae	unknown species (undes. strain)	
	Chlorophyceae	unknown species (undes. strain)	
	Chlorophyceae	unknown species (undes. strain)	
	Chlorophyceae	*Chlorella* sp.	
Cryptophyceae	Cryptophyceae	*Storeatula major*	5.30%
	Cryptophyceae	*Chroomonas* sp. 1	
	Cryptophyceae	*Cryptomonas* sp.	
	Cryptophyceae	*Cryptomonas* sp.	
	Cryptophyceae	*Hemiselmis* sp.	
	Cryptophyceae	*Cryptomonas* sp.	
Haptophyceae-A & Chrysophyceae-A & Dinophyceae-C	Haptophyceae-A	unknown species (undes. species)	11%
	Haptophyceae-A	unknown species (undes. strain)	
	Haptophyceae-A	*Isochrysis* sp.	
	Haptophyceae-A	*Pavlova* sp	
	Chrysophyceae-A	*Ochromonas* sp.	
Euglenophyceae	Euglenophyceae	*Euglena* sp.	2.20%

Table 3.4.1. CHEMTAX groups, the classes they represent, and the species used to derive the pigment ratio matrix. The groups are combined in this report as "Diatoms" (designated in green), "Harmful Taxa (designated in red), and "Mixed Flagellates (the remaining groups in black). Note that some taxa could not be differentiated based on pigment composition (e.g., Diatoms and Dinophyceae-A). Dinophyceae-B are species with peridinin while the other dinoflagellate types listed have fucoxanthin. Prasinophyceae-A and –B differ in that the latter has prasinoxanthin. Also shown is the mean % contribution to total pigment biomass of each group calculated from samples from all sites collected during 2001-2002.

3) "*Harmful Taxa*" that potentially include species that are known for producing toxic or nuisance blooms. Increases in the relative proportion of either of the latter groups to diatoms may be symptomatic of eutrophic conditions.

The relative contribution of each of these groups to total pigment biomass did not differ significantly in open water vs. creek sites (Figure 3.4.1). On average, diatoms made up 38% and 48% of biomass and harmful taxa represented 24% and 19% of the phytoplankton biomass in open water and creek sites, respectively. As mentioned above, the composition of phytoplankton in pristine North Inlet (tidal creek sites) in the summer is approximately 50%; therefore, the mean of 48% found here for all creek sites is probably indicative of overall good biotic condition, using North Inlet as a benchmark.

Based on recent discoveries of widespread harmful algal blooms in SC lagoonal stormwater detention ponds that exchange with tidal creeks (Lewitus and Holland, 2003; Lewitus *et al*., 2003; 2004b) and other harmful blooms found in SC tidal creeks and open estuaries (Keppler *et al*., in press), it is of interest to point out cases where relatively high contributions by these taxa were observed. It should be noted, however, that none of the SCECAP samples that contained these species showed evidence of blooms or harmful effects on fauna. In 2001, there were four open water sites where the potentially harmful taxa (Dinophyceae-B) exceeded 25% of pigment biomass, RO01108, RO01113, RO01121 (highest level at 41%), and RO01161. It is interesting to note that all of these sites were located in the Winyah Bay estuarine system. Three of these sites were ranked as "fair" in overall habitat quality and one of these sites (RO01113) had elevated nutrient concentrations. In contrast, the highest contribution of these taxa (Dinophyceae-B) at creek sites in 2001 was 1.4% at site NT01598, which is located in Shem Creek (Charleston Harbor). No other creek site had >0.05% Dinophyceae-B. In 2002, two open water sites (NO02302 and RO026014) and two creek sites (RT022022 and RT022027) had Dinophyceae-B contributions > 25% of biomass, with an exceptionally high level at RO026014 (53%), which is located in the Wando River of Charleston Harbor. Another intriguing annual difference was observed in the relative contribution of other harmful taxa (Cyanophyceae), which exceeded 10% in two open water sites and one creek site in 2001 (RO01125, RO01146, RT01642) but eight open water and eight creek sites in 2002, with the highest contribution at 24% of pigment biomass at RT022006, located in a creek behind Sullivans Island. The third harmful group of phytoplankton (Raphidophyceae-A group) is based on pigment ratios from *Heterosigma akashiwo*, a widespread pond bloom-former and a species that also formed a massive bloom in Bulls Bay in spring 2003. Annual variability was extreme. In 2001, Raphidophyceae-A comprised 35% of the total phytoplankton biomass at eight open water sites (including levels > 40% at RO01131 and RO01145), but only at two creek sites. In 2002, Raphidophyceae-A never contributed > 20% of the biomass at any site.

The value of these data on phytoplankton composition will be realized in long-term

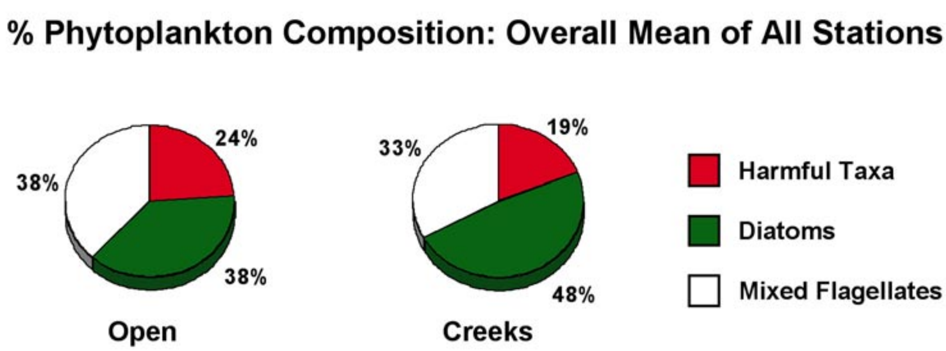


Figure 3.4.1. The percent contribution of Diatoms (green), Harmful Taxa (red), and Mixed Flagellates (white) to total phytoplankton community pigment biomass based on the mean of 2001-2002 samples from open water (left) and creek sites (right).

comparisons, when information on trends in relative composition will be available. Hypotheses explaining the extreme annual and, in some cases, regional variability in relative biomass of certain "harmful taxa" will be developed based on further analysis on finer temporal scales. However, when 2001 and 2002 data were combined in this analysis, no consistent correlations with nutrients or total chlorophyll *a* were observed.

Benthic Communities

During the 2001-2002 survey, 48,746 benthic organisms representing 370 taxa were collected (data online). Mean abundance of benthic organisms across all stations ranged from 138 to 22,038 individuals/m^2 (average = 5,208 individuals/m^2). The mean abundance of organisms collected at open water stations (5,589 individuals/m^2) was greater than the abundance at tidal creek stations (4,792 individuals/m^2), although the difference was not statistically significant ($p = 0.935$; Figure 3.4.2). The trend of higher densities of benthic organisms among open water stations when compared to tidal creek stations was also observed in 1999-2000 (Van Dolah *et al.*, 2002a). When comparisons between the 1999-2000 and 2001-2002 sampling periods are made within habitat type with respect to mean abundance, open water benthic infaunal abundances were very similar, while the mean abundance of organisms in tidal creek stations was greater during the 2001-2002 sampling survey. These differences were not statistically significant, likely due to high variance within sampling periods ($p > 0.05$).

The number of species ranged from three to 61 taxa per grab among all stations (average = 21), and overall community diversity (H') ranged from 0.70 to 4.85 (average = 2.86). A trend of higher values at open water sites compared to tidal creek sites was observed with respect to the mean number of species collected per grab (RO = 22, RT = 19; $p = 0.473$) and diversity (RO = 2.95, RT = 2.76; $p = 0.272$; Figure 3.4.2), although these differences were not statistically significant. Values for diversity and mean number of species per grab are similar to those reported for the 1999-2000 survey (Van Dolah *et al.*, 2002a).

The abundance and percent occurrence of the 50 numerically dominant taxa collected at all stations during 2001 and 2002 are presented in Table 3.4.2. These taxa comprised 83% of the overall abundance across all stations. The five dominant taxa across both years and all station types accounted for more than 35% of the total abundance and included the polychaete *Streblospio benedicti*, the oligochaete *Tubificoides wasselli*, and the polychaetes *Scoletoma tenuis*, *Mediomastus* sp., and *Parapionosyllis* sp. *Streblospio benedicti* was not only dominant numerically, but was found in 85% of the stations sampled. *Scoletoma tenuis* and *Mediomastus* sp. were collected in more than half of the sites sampled (59% and 55% of the stations, respectively). The distributions of *T. wasselli* and *Parapionosyllis* sp. were patchier; these taxa were found in only 38% and 16% of the stations sampled, respectively. Three of the five most numerically dominant taxa collected in

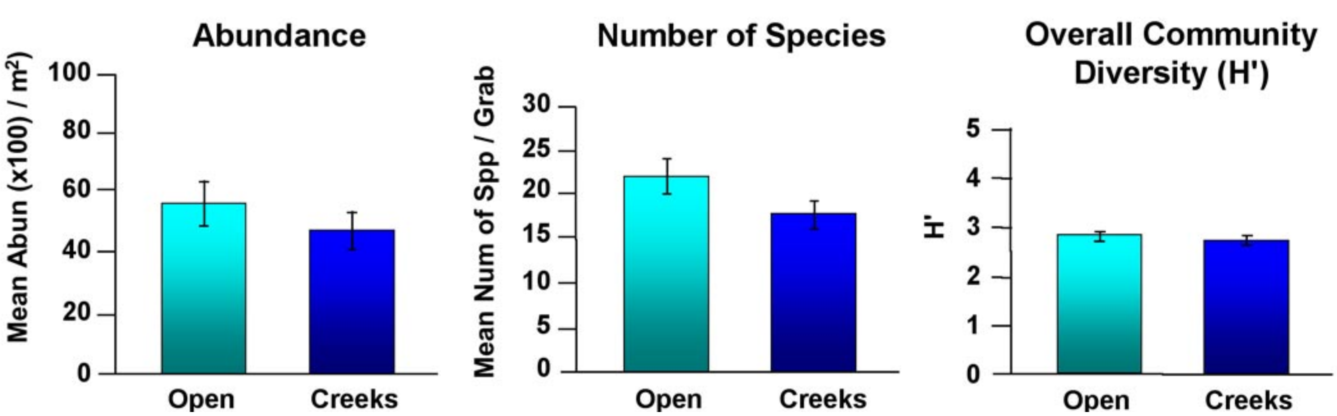


Figure 3.4.2. Mean abundance (number per m^2), number of species, and overall community diversity (H') of benthic fauna in bottom grabs (0.04 m^2) collected in open water and tidal creek habitats in 2001-2002.

Species Name		Mean Total Abundance at All Stations (#/0.04m^2)	Mean Total Abundance at All Stations (#/m^2)	Percent of Stations Where Present	Open Water Mean Abundance by Station (#/0.04m^2)	Open Water Percent of Stations Where Present	Tidal Creek Mean Abundance by Station (#/0.04m^2)	Tidal Creek Percent of Stations Where Present
Streblospio benedicti	P	4269	106,725	85	37	79	36	93
Tubificoides wasselli	O	1298	32,450	38	13	44	9	30
Scoletoma tenuis	P	1191	29,775	59	7	49	14	70
Mediomastus sp.	P	1019	25,463	55	11	59	6	50
Parapionosyllis sp.	P	853	21,313	16	10	21	5	11
Caulleriella sp.	P	823	20,575	23	7	34	7	11
Exogone sp.	P	724	18,088	35	6	33	6	38
Aphelochaeta sp.	P	719	17,975	27	5	21	8	34
Tharyx acutus	P	628	15,700	50	5	44	5	57
Ampelisca abdita	A	538	13,438	38	7	38	2	38
Tubificidae	O	491	12,263	44	4	38	5	52
Sabellaria vulgaris	P	427	10,663	29	6	31	2	27
Tubificoides brownae	O	425	10,613	42	3	31	5	54
Cirratulidae	P	399	9,975	46	3	51	4	41
Streptosyllis sp.	P	383	9,563	32	4	33	3	30
Polydora cornuta	P	365	9,113	38	3	31	4	46
Spiochaetopterus costarum oculatus	P	354	8,850	41	2	36	4	46
Scoloplos rubra	P	320	7,988	44	1	31	5	59
Mediomastus californiensis	P	262	6,550	26	2	30	2	21
Paraprionospio pinnata	P	262	6,550	37	2	36	2	38
Aricidea wassi	P	254	6,338	21	3	31	1	11
Polycirrus sp.	P	245	6,125	15	1	15	3	14
Clymenella torquata	P	227	5,663	20	4	25	0	14
Mediomastus ambiseta	P	226	5,650	33	3	38	1	29
Cirrophorus sp.	P	212	5,300	21	1	25	3	18
Heteromastus filiformis	P	212	5,288	56	1	43	2	71
Carinomella lactea	O	200	5,000	44	1	44	2	43
Polydora socialis	P	197	4,913	28	2	30	1	27
Nemertea	O	180	4,488	67	2	72	1	61
Batea catharinensis	A	179	4,463	31	2	34	0	27
Leptonacea sp.	M	172	4,300	32	2	36	1	29
Tellina agilis	M	168	4,188	32	1	36	2	29
Tubificidae sp. b	O	161	4,025	13	1	16	2	9
Monticellina sp.	P	141	3,513	26	1	26	2	25
Nereis succinea	P	137	3,425	37	1	30	1	45
Unciola serrata	A	136	3,400	14	2	16	0	11
Sphenia antillensis	M	135	3,375	13	2	15	1	11
Phoronida	O	127	3,175	13	1	11	2	14
Pelecypoda	M	125	3,125	37	2	48	0	25
Pinnixa sp.	O	122	3,038	30	1	33	1	27
Enchytraeidae	O	119	2,975	4	2	8	0	0
Nucula sp.	M	112	2,800	29	1	31	1	27
Paracaprella tenuis	A	108	2,700	30	1	28	1	32
Podarkeopsis levifuscina	P	107	2,675	36	1	36	1	36
Cyathura burbancki	O	106	2,638	17	1	20	0	14
Eobrolgus spinosus	A	89	2,225	9	1	11	0	7
Glycera americana	P	87	2,163	56	1	62	1	50
Leitoscoloplos fragilis	P	86	2,138	33	1	36	1	30
Dulichiella appendiculata	A	82	2,050	9	1	8	1	11
Spiophanes bombyx	P	81	2,013	24	1	26	1	21

Table 3.4.2. Abundance (number per 0.04 m^2 and number per m^2) and percent occurrence of the 50 most numerically dominant benthic organisms collected in 2001 and 2002. A = amphipod, M = mollusk, P = polychaete, and O = other taxa.

2001-2002 were also among the five dominant taxa collected in 1999-2000: *S. benedicti*, *S. tenuis*, and *T. wasselli* (Van Dolah *et al.*, 2002a).

Among the open water stations, the five most abundant taxa, *S. benedicti*, *T. wasselli*, *Mediomastus* sp., *Parapionosyllis* sp., and the polychaete *Caulleriella* sp., comprised more than 34% of the total abundance. The five most abundant taxa at tidal creek stations composed over 38% of the total abundance. These included *S. benedicti*, *S. tenuis*, *T. wasselli*, the polychaete *Aphelochaeta* sp., and *Caulleriella* sp.

Streblospio benedicti, the dominant taxon in both open water and tidal creek habitats, was found in significantly greater abundance at open water stations than tidal creek stations ($p = 0.038$). The oligochaete *T. wasselli* was the second most numerically dominant species at open water stations, and was among the five most abundant taxa at tidal creek stations. Abundances of this species were not significantly different between open water and tidal creek stations ($p = 0.173$). *S. tenuis* was the second most abundant species collected at tidal creek stations, and was found in 49% of the open water stations, where it ranked seventh in abundance. The abundances of this polychaete were significantly different between open water and tidal creek stations ($p = 0.002$; Figure 3.4.3).

All benthic species were placed into one of four groups (polychaetes, amphipods, mollusks, or other taxa) to evaluate general taxonomic composition. Polychaetes were the dominant taxonomic group, comprising 65% and 75% of the total abundance in open water and tidal creek stations, respectively (Figure 3.4.4). Organisms in the "other taxa" category, such as oligochaetes, nemerteans, isopods, and decapods, comprised 17% of the total abundance at open water stations, and 16% of the total abundance at tidal creek stations. Amphipods comprised 11% of the total abundance at open water stations and 5% at tidal creek stations, while mollusks were the least abundant taxonomic group (7% of total abundance at open water stations and 4% at tidal creek stations; Figure 3.4.4).

The mean abundance of mollusks and amphipods was greater in open water habitats, while the opposite trend was observed for polychaetes and organisms representing the "other taxa" category. Abundances of the different taxonomic groups were not significantly different between habitat types during the 2001-2002 sampling period ($p > 0.05$). Similar taxonomic composition was observed during the 1999-2000 survey (Van Dolah *et al.*, 2002a). Slightly higher percentages of polychaetes were found in each station type in 2001-2002 when compared to the 1999-2000 survey, with associated decreases in the percent contribution of amphipods and organisms

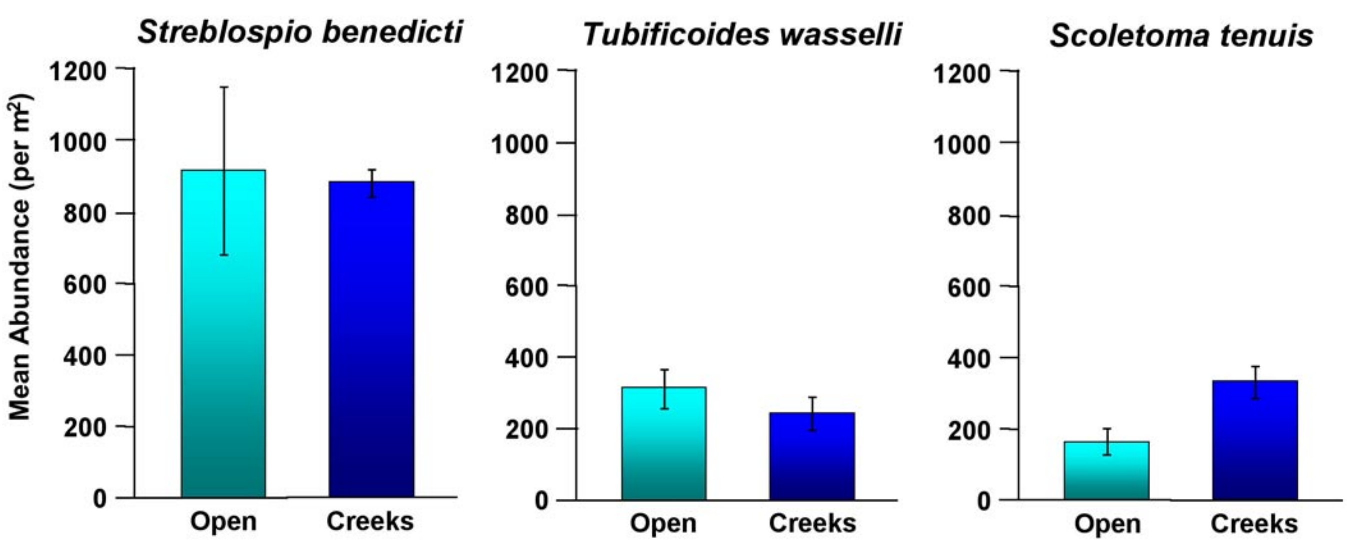


Figure 3.4.3. Abundance (number per m²) of three numerically dominant species, Streblospio benedicti, Tubificoides wasselli, and Scoletoma tenuis, collected in benthic grabs at open water and tidal creek stations during 2001-2002.

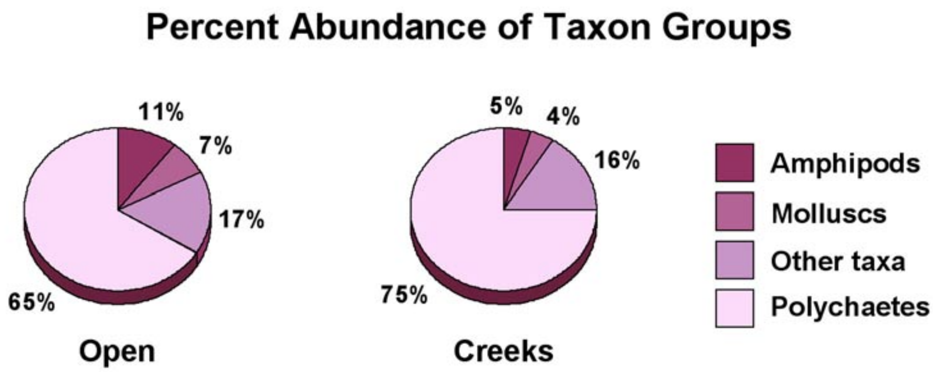


Figure 3.4.4. Percent of total faunal abundance representing general taxonomic groups collected in benthic grabs at open water and tidal creek sites during 2001-2002.

in the other taxa category. Mollusk abundances remained very similar across surveys.

The number of species falling into each general taxonomic category varied by station type. Open water stations had 134 polychaete species, 58 mollusk species, 48 amphipod species, and 85 other taxa. The taxonomic breakdown of tidal creek stations included 118 polychaete species, 44 mollusk species, 38 amphipod species, and 56 other taxa. The differences in the number of species in these taxonomic groups were not significantly different between tidal creek and open water habitats ($p > 0.05$).

Several metrics summarizing benthic community condition, including abundance, number of species, and abundance of sensitive taxa have been integrated into a single multi-metric benthic index of biological integrity (B-IBI) that was developed for southeastern estuaries to distinguish between degraded and undegraded environments (Van Dolah *et al.,* 1999). The B-IBI is used as the primary measure of biotic condition for SCECAP. Benthic invertebrate communities provide one of the best measures of biotic condition because most of the organisms are sessile, they have the greatest exposure to poor sediment quality (e.g., elevated contaminants) since they live in the sediments, and they are exposed to bottom waters, which often are of poorer quality than the surface waters. Furthermore, the B-IBI developed for this region has been demonstrated to have a high correspondence with sediment quality conditions. Until the relationships between fish and phytoplankton measures versus environmental quality condition are better understood, the B-IBI will serve as the only measure of biotic condition in the overall integrated habitat quality score.

The majority of South Carolina's coastal habitat sampled in 2001-2002 had B-IBI values > 2.5, indicating undegraded benthos, which was the same trend observed in 1999-2000 (Van Dolah *et al.*, 2002a). Degraded benthos (B-IBI ≤ 1.5) were observed at 3% of open water habitats and 4% of tidal creek habitats. In the 1999-2000 sampling period, the percentage of habitat with degraded benthos (open water = 2%, tidal creek = 4%) was similar to the 2001-2002 values in both habitat types. Possible degradation of benthos, with B-IBI values ranging from 2.0 to 2.5, was found at 14% of the open water stations and 27% of the tidal creek stations in the 2001-2002 survey (Figure 3.4.5). These results indicate a 15% increase in the percentage of habitat coding as fair in tidal creek habitats, and a 2% increase in the percentage of habitat coding as fair in open water habitats when compared to the 1999-2000 survey (open water = 12%, tidal creek = 12%).

An examination of the trends in the B-IBI on an annual basis also clearly indicate an increase in the percentage of the state's habitat falling in the fair category in 2001 and 2002 (Figure 3.4.6). These changes in benthic community condition over time may be related to changes in sediment quality, since we observed some increase in the percentage of habitat coding as fair with respect to the integrated sediment quality score in 2001 and 2002 (Figure 3.3.9). In contrast, the integrated water quality score showed little change over the four-year period evaluated (see Figure 3.2.15), and trends in the B-IBI are unlikely related to these parameters.

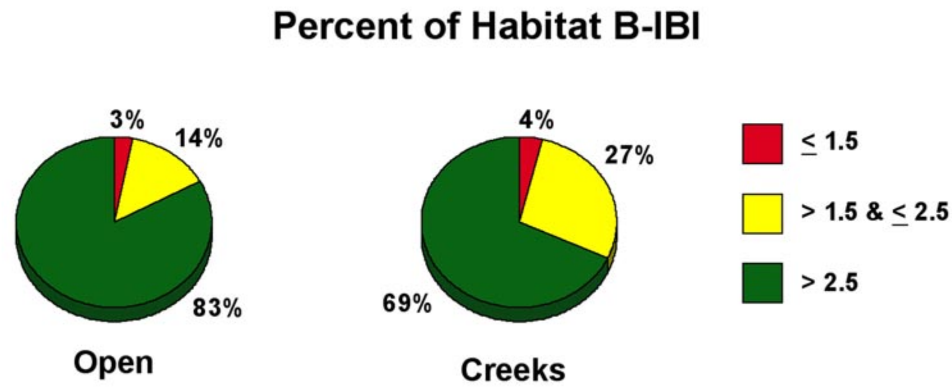


Figure 3.4.5. Estimates of the percent of the state's coastal habitat representing benthic index of biological integrity (B-IBI) values that represent undegraded (> 2.5, green), marginally degraded (> 1.5 and ≤ 2.5, yellow) or degraded (≤ 1.5, red) benthic communities as developed by Van Dolah et al. (1999).

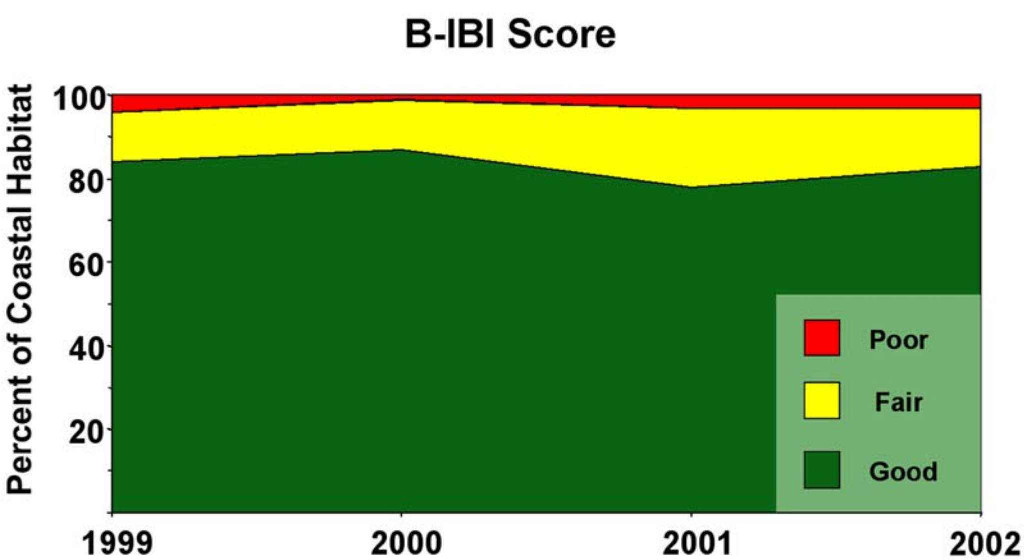


Figure 3.4.6. The proportion of South Carolina's estuarine habitat that ranks as good (green), fair (yellow), or poor (red) using benthic index of biological integrity (B-IBI) values developed by Van Dolah et al. (1999).

Additional analyses were completed comparing benthic measures within each sampling year to determine if significant variability among habitat types occurred. In 2001, no significant differences in the abundance of benthic organisms, the number of species per grab, or overall community diversity were found between tidal creek and open water habitats ($p > 0.05$). Each of these measures were similar in tidal creek and open water habitats (abundance, RT mean = 4,710 individuals/m^2, RO mean = 4,095; number of species, RT mean = 18 taxa/grab, RO mean = 17; H', RT mean = 2.8, RO mean = 2.7). No significant differences in the abundances of organisms falling in the general taxonomic groups of polychaete, amphipod, mollusk, and other taxa were found between habitat types ($p > 0.05$). Likewise, no significant difference was found between habitat types for the number of species falling into each of these general taxonomic categories in 2001 ($p > 0.05$).

In 2002, the abundance of benthic organisms, the number of species, and overall community diversity were not significantly different between habitat types ($p > 0.05$). Contrary to the trend observed for 2001 data, all of these measures were consistently higher in open water than tidal creek habitats in 2002 (abundance, RT mean = 4,859 individuals/m^2, RO mean = 7,035; number of species, RT mean = 20 taxa/grab, RO mean = 26; H', RT mean = 2.7, RO mean = 3.1). The abundances of organisms in each general taxonomic group were not significantly different between habitat types. The number of species in the "other taxa" category was significantly higher in open water stations than tidal creek stations ($p = 0.042$). This trend appears to be driven by several decapod and mysid species ($n = 13$ and $n = 5$, respectively) that were found in open water habitats in 2002, but not in tidal creek habitats. No statistically significant difference in the number of species of polychaetes, mollusks, or amphipods were observed between habitat types ($p > 0.05$).

Finfish and Crustacean Communities

Estuarine waters provide important habitats for a diverse and transitory finfish and crustacean assemblages. These areas supply food, refuge from predators, and valuable habitats that are utilized by egg, larval, juvenile, and adult stages of a variety of species (Joseph, 1973; Mann, 1982; Nelson *et al.,* 1991). The organisms inhabiting tidal creeks encounter complex natural variations in physical, chemical, and biological factors, in addition to anthropogenic stresses from upland development. These factors strongly influence the accessibility and variety of estuarine habitats, consequently affecting the distribution, diversity, and abundance of the organisms occurring in estuarine habitats (Monaco *et al.,* 1992).

The trawl catch data collected during the 2001-2002 sampling period were generally based on organisms that were larger than 2-3 centimeters in size, and slow enough to be captured in the trawl net used for the program. Abundance values were standardized to the number of individuals per hectare, and can therefore be compared between habitat types, even though trawls were shorter at tidal creek stations (0.25 km) than open water stations (0.50 km). It is important to note that the number of species and diversity indices cannot be easily normalized using the same process. However, as noted below, even though tows in tidal creek habitats were shorter, these areas consistently had a greater number of species per trawl and higher overall community diversity (H') than open water stations.

A total of 14,631 organisms representing 63 species were collected by trawl during the 2001-2002 survey (data online). Mean abundance across all stations ranged from four to 8,333 individuals per hectare (average = 685 individuals/hectare). The mean abundance in tidal creeks (924 individuals/hectare) was nearly twice the mean abundance in open water habitats (466 individuals/hectare), and represented a statistically significant difference ($p < 0.001$). The trend of higher mean faunal densities in tidal creek stations when compared to open water stations was also observed in 1999-2000 (Van Dolah *et al*., 2002a). When comparisons between the 1999-2000 and 2001-2002 sampling periods are made within station type with respect to mean abundance, both open water and tidal creek abundances were greater during the 2001-2002 sampling season.

The number of species collected across all stations ranged from one to 14 per trawl (average = 6), and overall community diversity ranged from zero to 2.91 (average = 1.62). Mean values for tidal creek stations, even with shorter tow lengths, were slightly higher than those observed in open water habitats with respect to the number of species collected per tow (RO = 5.9, RT = 6.3; $p = 0.498$) and diversity (RO = 1.59, RT = 1.65; $p = 0.777$; Figure 3.4.7), although these differences were not statistically significant. Similar trends were observed for both species numbers and diversity in 1999-2000 (Van Dolah *et al*., 2002a).

The abundance (individuals per hectare) and percent occurrence of the 50 numerically dominant taxa across both habitat types in 2001 and 2002 are presented in Table 3.4.3. These taxa comprised 99.9% of the overall abundance across all stations, and included 22 recreationally and/or commercially important species (indicated in bold text). The five dominant species accounted for nearly 75% of the total abundance, and were all recreationally important species. These included white and brown shrimp (*Litopenaeus setiferus* and *Farfantepenaeus aztecus*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), and silver perch (*Bairdiella chrysoura*). White shrimp and spot were

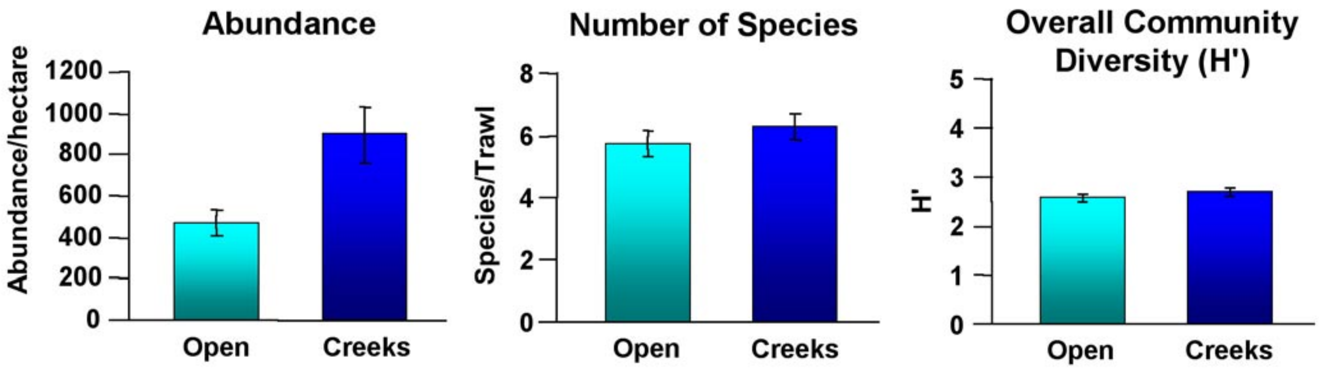


Figure 3.4.7. Mean abundance, number of species, and overall community diversity (H') collected in trawls in open water and tidal creek sites during 2001-2002.

found at more than half of the stations sampled, and were present at a larger number of tidal creek stations than open water stations (white shrimp, 48% of open water stations and 62% of tidal creek stations; spot, 65% of open water stations and 78% of tidal creek stations). Brown shrimp, also collected at over 50% of the stations overall, were found at roughly similar numbers of open water (67%) and tidal creek stations (62%). Atlantic croaker and silver perch were found at fewer than half of the stations sampled. Atlantic croaker were collected at a greater number of open water stations (57%) than tidal creek stations (35%), while the opposite trend was observed for silver perch (30% of open water stations, and 58% of tidal creek stations). Four of the five most numerically dominant taxa collected in 2001-2002 were also among the five dominant taxa collected in 1999-2000: *L. setiferus*, *F. aztecus*, *L. xanthurus*, and *B. chrysoura* (Van Dolah *et al*., 2002a).

Within open water stations, the five numerically dominant species, white shrimp, brown shrimp, Atlantic croaker, spot, and star drum (*Stellifer lanceolatus*), comprised more than 76% of the total abundance. The five dominant taxa in tidal creek habitats, comprising more than 82% of the total abundance, were white shrimp, brown shrimp, spot, silver perch, and pinfish (*Lagodon rhomboides*). White shrimp, the most abundant species in both open water and tidal creek habitats, were found in significantly greater numbers at tidal creek stations (p = 0.010; Figure 3.4.8). The abundance of white shrimp displayed a similar pattern in the 1999-2000 survey (Van Dolah *et al*., 2002a). The abundance of the second most numerically dominant organism, brown shrimp, was not significantly different between open water and tidal creek habitats (p = 0.532). Atlantic croaker, which ranked third in abundance at open water stations and eighth in abundance at tidal creek stations, were found in significantly greater densities in open water than tidal creek habitats (p = 0.035). Spot was the fourth most abundant species in open water habitats, and ranked third in abundance at tidal creek stations. The abundance of this species was greater in tidal creek habitats than open water stations at statistically significant levels (p = 0.015; Figure 3.4.8).

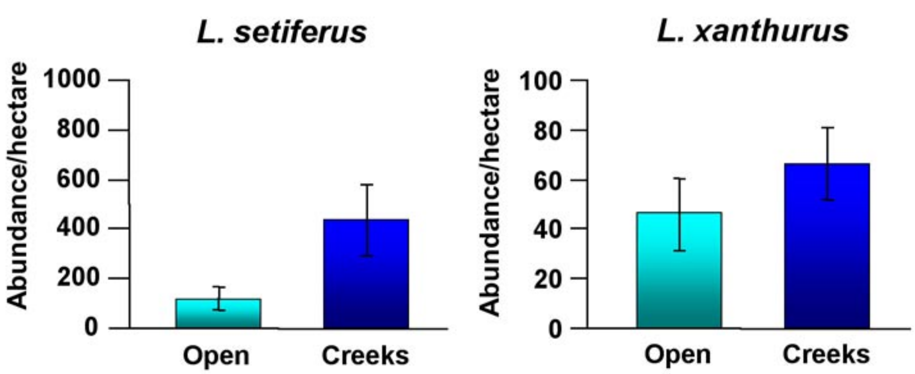


Figure 3.4.8. Mean abundance of two recreationally important species, white shrimp (Litopenaeus setiferus) and spot (Leiostomus xanthurus), collected in trawls in open water and tidal creek habitats during 2001-2002.

Differences in the finfish and crustacean communities between tidal creek and open water habitats may be explained by gear effectiveness in different habitat types, as well as by the physiological and behavioral responses of different species and life stages to the physical characteristics of these habitats. Due to the smaller size of tidal creeks compared to open water areas, a trawl may be more efficient in collecting organisms in these areas. In some tidal creeks, the trawl extended from bank to bank and would have likely entrained most of the organisms in its path. Jutte *et al*. (2004) analyzed SCECAP trawl data collected in tidal creeks from 1999-2002, and found that increases in various trawl biological metrics (e.g., overall abundance, abundance of Atlantic croaker, number of species) were most strongly linked to low dissolved oxygen levels, high turbidity levels, and a large number of rivulets. The increased faunal abundance and number of species in tidal creek habitats where low dissolved oxygen levels were more common (Figure 3.2.2) suggests that these organisms, whose tolerance of low oxygen levels varies among species and life stage (Dorfman and Westman, 1970; Burton *et al*., 1980; Wannamaker and Rice, 2000), may be using tidal creek habitats as refuges from predators. Estuarine organisms have also been documented to opportunistically feed on benthic infauna that emerge as a result of hypoxic conditions (Llanso, 1992; Pihl *et al.,* 1992), which might also explain the increased densities of fish and crustaceans in shallow tidal creeks with low dissolved oxygen levels. An alternative hypothesis is that species inhabiting these creeks suffer from physiological effects related to low dissolved oxygen levels that reduce their overall fitness, and consequently they are more susceptible to capture by the trawl net. Increased ventilation rates in poorly oxygenated waters can affect allocation of energy to various metabolic activities, and result in reduced fitness (Steffensen *et al*., 1982; Kramer, 1987; Pihl *et al*., 1991). Finally, the increased turbidity levels found at these sites (Figure 3.2.12) may create increased protection against predators (Baltz *et al.,* 1993).

More than 12,050 recreationally important fish and crustaceans were collected during the 2001-2002 sampling season. These taxa, representing 24 species of fish and crustaceans, accounted for 84% of the total abundance of organisms collected (Table 3.4.3; data online). In the 1999-2000 survey, recreationally important taxa comprised 75% of the total abundance of organisms collected. Recreationally important taxa were significantly more abundant in tidal creek habitats (average = 800 individuals/hectare) than open water areas (368 individuals/hectare; $p = 0.013$) during the 2001-2002 survey. The number of recreationally important species collected in open water (average = 3.4 species/trawl) was very similar to the number encountered in tidal creek habitats (3.8 species/trawl), and the difference was not significant ($p = 0.231$). However, as noted previously, unlike abundance estimates, species counts cannot be normalized for trawl length, and open water trawls were twice the length of trawls made in tidal creeks.

The mean lengths of the three dominant taxa collected during the 2001-2002 survey were analyzed to determine if any relationship existed between organism size and habitat type. White shrimp, brown shrimp, and spot collected in open water habitats had significantly greater lengths than those collected at tidal creek stations ($p < 0.05$). To assess the association between organism length and station depth, non-parametric correlation analyses (Spearman's Rho and Kendall Tau b) were completed. White shrimp lengths displayed a positive correlation with station depth (correlation coefficient = 0.35, $p < 0.05$). A positive correlation with station depth was also observed with respect to brown shrimp length (correlation coefficient = 0.26, $p < 0.05$). The mean length of spot was not significantly correlated with station depth ($p > 0.05$). These results support the premise that smaller, and typically shallower, tidal creek habitats do serve an important function as nursery habitat.

Analyses of trawl data were also conducted to determine if significant variability occurred between habitat types within sampling year. In 2001, trawl catches had significantly greater mean abundances in tidal creek habitats than open water habitats ($p = 0.002$). The mean number of species and overall community diversity were also greater in tidal creek habitats, although these differences were not statistically significant ($p > 0.05$). White shrimp, brown shrimp, spot, and silver perch abundances were all greater in tidal creek habitats than open

				Open Water		Tidal Creek	
Species Name	**Common Name**	**Total Abundance at All Stations (#/hectare)**	**Percent of Stations Where Present**	Mean Abundance by Station (#/hectare)	Percent of Stations Where Present	Mean Abundance by Station (#/hectare)	Percent of Stations Where Present
Litopenaeus setiferus	white shrimp	31,231	55	110	48	448	62
Farfantepenaeus aztecus	brown shrimp	11,560	64	87	67	116	62
Leiostomus xanthurus	spot	6,673	71	46	65	71	78
Micropogonias undulatus	Atlantic croaker	5,342	46	74	57	17	35
Bairdiella chrysoura	silver perch	4,031	43	6	30	67	58
Lolliguncula brevis	brief squid	3,812	65	13	60	55	71
Lagodon rhomboides	pinfish	3,489	41	6	22	57	62
Stellifer lanceolatus	star drum	2,479	23	40	43	1	2
Cynoscion regalis	weakfish	2,374	46	32	58	8	33
Trinectes maculatus	hogchoker	1,607	30	14	25	14	36
Anchoa mitchilli	bay anchovy	1,492	39	6	32	21	47
Callinectes similis	lesser blue crab	997	41	8	45	9	36
Chaetodipterus faber	Atlantic spadefish	507	25	3	22	6	29
Orthopristis chrysoptera	pigfish	506	26	3	17	6	36
Callinectes sapidus	blue crab	362	17	1	15	5	20
Chloroscombrus chrysurus	Atlantic bumper	330	10	5	12	1	7
Selene vomer	lookdown	239	21	2	18	2	24
Opsanus tau	oyster toadfish	208	19	1	8	3	31
Citharichthys spilopterus	bay whiff	138	9	0	5	2	13
Farfantepenaeus duorarum	brown-spotted/pink shrimp	125	9	1	8	1	9
Brevoortia tyrannus	Atlantic menhaden	105	12	0	8	1	16
Symphurus plagiusa	blackcheek tonguefish	87	13	1	18	1	7
Menticirrhus americanus	southern kingfish	80	12	1	23	0	0
Gymnura micrura	smooth butterfly ray	80	11	0	12	1	11
Stephanolepis hispidus	planehead filefish	79	7	1	10	0	4
Paralichthys lethostigma	southern filefish	73	8	0	3	1	13
Etropus crossotus	fringed flounder	72	4	0	3	1	5
Gerreidae	mojarras	65	2	0	0	1	4
Synodus foetens	inshore lizardfish	54	5	0	5	1	5
Dasyatis sabina	Atlantic stingray	51	10	0	13	0	5
Chilomycterus schoepfi	striped burrfish	51	7	0	8	0	5
***Menticirrhus* sp.**		47	8	0	8	1	7
Centropristis philadelphica	rock sea bass	47	7	0	7	1	7
Opisthonema oglinum	Atlantic thread herring	43	1	0	0	1	2
Paralichthys dentatus	summer flounder	40	7	0	8	0	5
Lepisosteus osseus	longnose gar	40	3	0	2	1	5
Peprilus alepidotus	harvestfish	36	6	0	10	0	2
Sphoeroides maculatus	northern puffer	29	3	0	5	0	0
Anchoa hepsetus	striped anchovy	25	3	0	7	0	0
Cynoscion nebulosus	spotted sea trout	22	2	0	0	0	4
Dorosoma cepedianum	gizzard shad	22	1	0	0	0	2
Bagre marinus	gafftopsail catfish	18	3	0	2	0	4
Citharichthys sp.		14	2	0	0	0	4
Lutjanus synagris	lane snapper	14	2	0	3	0	0
Dasyatis sayi	bluntnose stingray	12	2	0	3	0	0
Aluterus schoepfi	orange filefish	7	2	0	3	0	0
Pogonias cromis	black drum	7	2	0	3	0	0
Rhizoprionodon terraenovae	Atlantic sharpnose shark	7	2	0	3	0	0
Ariopsis felis	sea catfish	7	1	0	0	0	2
Eucinostomus gula	silver jenny	7	1	0	0	0	2

Table 3.4.3. The abundance (number per hectare) and percent occurrence of the 50 numerically dominant taxa collected by trawl during 2001 and 2002, which represent 99.9% of the overall abundance. Recreationally important taxa are in bold text.

water sites in 2001 catches. These differences were significant with respect to spot ($p = 0.043$) and silver perch ($p = 0.007$). The trend was reversed in Atlantic croaker, where abundances in trawl catches were greater at open water stations than tidal creek sites. When analyses of 2001 catches were limited to recreationally important species, results indicated that significantly greater abundances of these organisms were collected in tidal creeks than open water habitats ($p = 0.004$), although the number of recreationally important taxa collected in each habitat type was similar ($p > 0.05$).

Comparisons between habitat type for trawl catches collected in 2002 were similar to those collected in 2001. In 2002, the abundance of fish and crustaceans collected by trawl in tidal creeks was significantly greater than the catch in open water habitats ($p = 0.013$). Community diversity and species numbers were not significantly different between habitat types ($p > 0.05$). With respect to dominant taxa collected in the 2002 sampling season, white shrimp, brown shrimp, spot, and silver perch were found in greater abundances in tidal creeks than open water habitats. Abundances of white shrimp and silver perch represent statistically significant differences between habitat type ($p = 0.048$, and $p = 0.005$, respectively). Abundances of Atlantic croaker were significantly higher in open water habitats than tidal creeks ($p = 0.014$). Recreationally important fish and crustaceans collected by trawl in 2002 were found in significantly higher abundances at tidal creek versus open water stations ($p < 0.001$), but the number of species was not significantly different between habitat types ($p > 0.05$).

The lower 50th, 25th, and 10th percentiles of mean abundance/hectare, mean species number, and mean community diversity (H') in open water and tidal creek habitats are presented in Table 3.4.4. Four open water stations fell below the 10th percentile for each of these metrics: RO026016, RO026026, RO026018, and RO026290. Two tidal creek stations, RT022030 and RT022007, had mean abundance/hectare and mean species numbers below the 10th percentile, while no stations were below the 10th percentile for all three metrics. Two of these six stations (RO026016 and RT022030) had no catch in one of the two replicate trawls, although the trawls were considered to be valid tows by field crews. Based on the overall integrated measure of habitat quality (Appendix 2), all but one of these six stations was coded as having good habitat quality. Station RT022007 was coded as having fair habitat quality, with an overall good water quality score, but fair condition for both sediment and biological quality. A review of the environmental parameters associated with the six stations that had two to three trawl metrics falling in the lower 10th percentile showed that one or more parameters were elevated in most cases. These parameters included high contaminant ERM-Q, a toxic bioassay, poor benthic index of biological integrity (B-IBI), and/or water quality parameters above the 75th or 90th percentile for fecal coliform bacteria and pH.

Due to the population problems that have been observed in blue crabs (*Callinectes sapidus*) in the state of South Carolina and along the eastern seaboard (Eggleston, 2003), additional analyses were conducted to determine if significant trends in abundance of this species were observed during the survey. The mean abundance of blue crabs in tidal creeks (5.4 individuals/hectare) was greater than the mean abundance in open water habitats (1.1 individuals/hectare), although this was not a statistically significant difference ($p > 0.05$). The abundances of blue crabs were also not significantly different by year when habitat types were analyzed together ($p > 0.05$).

	Abundance/area		Species Number		Overall Community Diversity (H')	
	Open	Creeks	Open	Creeks	Open	Creeks
mean	466.5	924.5	5.9	6.3	1.59	1.66
10th percentile	29.4	134.8	2.0	3.0	0.47	0.71
25th percentile	76.6	210.1	3.1	4.5	1.10	1.10
50th percentile	233.7	518.7	5.8	6.0	1.68	1.86

Table 3.4.4. Mean values and the 10th, 25th, and 50th percentiles for abundance/hectare, number of species collected, and overall community diversity (H') values for open water and tidal creek sites.

As part of a related study to SCECAP, a preliminary estuarine biotic integrity (EBI) index was developed using finfish collected in trawl catches in tidal creek habitats from 1999-2002 (Moy, 2004). Multimetric index approaches have proven to be more effective for environmental assessments than relying solely upon independent metrics (e.g., Karr, 1991; Yoder and Rankin, 1995; Deegan *et al.*, 1997) or multivariate analyses (e.g. Fausch *et al.*, 1990; Van Dolah *et al.,* 1999). The EBI index incorporated nine metrics describing the finfish community (overall density, number of taxa, species diversity (H'), percent dominance of the most abundant species, number of estuarine nursery taxa, number of estuarine resident taxa, number of estuarine spawning taxa, percent of benthic-dwelling taxa, and density of flounder) and was modified from approaches developed by Deegan *et al*. (1993, 1997) and Meng *et al*. (2002). Analyses conducted to date indicate that while various fish community metrics were sensitive to environmental quality, the EBI index had high error rates and did not adequately reflect estuarine biotic integrity. These high error rates were due in large part to the lack of variation in the environmental quality of tidal creek stations sampled during 1999-2002. However, the EBI index should prove to be a useful tool in the future, particularly as data from ongoing SCECAP sampling, as well as results from other NCA-funded studies in neighboring states, can be incorporated to further develop the index.

Historically, macroinvertebrates have been popular indicators for surveying environmental conditions, and a benthic index of biological integrity (B-IBI) has been successfully developed for the southeastern region to distinguish between degraded and undegraded environments (Van Dolah *et al*., 1999). The SCECAP survey currently uses this B-IBI as the single measure of biological impairment. Therefore, while SCECAP will continue to collect and interpret the finfish community found in trawl catches, for the present time the program will rely solely on the B-IBI to evaluate the biological condition of South Carolina's estuarine habitats.

Contaminant Levels in Fish Tissue

The bioaccumulation of contaminants such as DDT and methyl-mercury are issues of both local and national concern. In estuarine systems, many organisms including shrimp, crabs, and fish can be exposed to contaminants through contact with polluted sediments. While the extent of area of polluted sediments in South Carolina is low when compared to more developed estuaries in the Northeast or Gulf states (USEPA, 2001) there is still the potential for bioaccumulation of contaminants. Of primary concern from a human-health standpoint is methyl-mercury. However, other contaminants such as metals, PAHs, PCBs, and DDT and other pesticides all have the potential of bioaccumulating in animal tissue. PAHs, however, may have a lower bioaccumulation potential because these compounds can be broken down by metabolic processes in fish (Johnson *et al.*, 2002).

In general, the fish collected by SCECAP are small (2-10 cm), so whole fish are processed rather than just the fillets to better represent bioaccumulation. The whole body contaminant data collected by SCECAP is an environmental measure of contaminants in fish tissues and should not be directly compared to edible tissue concentrations (fillets only) often used as a measure of risk to humans. Use of whole fish may underestimate the concentration of some contaminants (e.g., mercury) in edible tissue, but provides a better estimate of overall contaminant concentration in the organism compared to just analyzing fillets.

For the 2001 and 2002 sampling periods, fish tissues were collected at 48 and 53 stations, respectively. The target species were spot (*Leiostomus xanthurus*) and croaker (*Micropogonias undulatus*), both bottom feeders, with other species such as silver perch and pinfish substituted when the two target species were not collected (data online). A few stations each year had no appropriate species for tissue contaminant analysis (2001, n = 7; 2002, n = 9).

Comparisons were made between SC tissue contaminant levels and other southeastern states using results from the NCA Program database for 2000 and 2001. Stations were identified where contaminants exceeded maximum concentrations for the Southeast. This occurred at five stations for three different contaminants. The contaminants were PCB 77 (station NT01599), Gamma-HCH (g-BHC, lindane) (stations RO026004, RO026010, and RT022019), and heptachlor (station RT022002). These findings are consistent with the levels of fish tissue contaminants collected in South Carolina by SCECAP during 2000, where only one station had elevated levels of anthracene and fluorene (Van Dolah *et al*., 2002a).

A second approach used to help identify stations with potential tissue contamination issues was to identify individual contaminants that exceeded the 90th percentile of the SCECAP data set (2000-2002). Once contaminant values greater than their respective 90th percentile were identified at each station, the total number of exceedances at each station was generated (data online). This approach identifies those sites with relatively high fish contaminant concentrations in the SCECAP database, but these contaminant levels do not necessarily indicate potentially harmful concentrations. Exceedance values ranged from zero (no contaminants exceeded their respective 90th percentile value) to 31 exceedances at station RT01650.

Of the seven random stations that had 16 or more exceedances, three of the stations were in urbanized rivers (RT01650 in Little River Inlet and RO026030 and RT01628 in the Ashley River). The final four stations were in the Wando River (RO01162), South Santee River (RO026004), North Inlet (RT01645), and the Whale Branch (RO01132), where possible sources of contamination are less clear. When compared to the 2000 data in the 1999-2000 survey, there were a similar number of stations with a high number of exceedances (4 stations in 2000). In general, southeastern estuaries have lower tissue contaminant levels when compared to estuaries on the Northeast, West or Gulf coasts (EPA, 2001; in review), which reflects the overall lower level of pollutants in SE estuaries.

3.5 Incidence of Litter

At each station, a visual census of litter was completed. Included in the census was material found floating or caught in the edges of the marsh. It also included litter and pieces of crab trap caught in the trawl.

During the 2001-2002 survey, a total of 18 of the 115 random stations had some type of litter. Broken down by habitat type, six of the open water stations and 12 of the tidal creek stations had litter (representing 8% and 20% of each habitat respectively based on CDF analyses). The difference is probably related to the relative proximity of tidal creeks to upland areas and probable source of litter, combined with the fact that tidal creek marsh surface and banks are more likely to retain trash that is viewable compared to open water sites not close to any shoreline.

When compared to the 1999-2000 survey, there was a much higher percentage of litter in 2001-2002. This trend will need to be carefully monitored in the future as increased human activity in our estuarine waters is likely to result in an increase in the litter problem.

3.6 Integrated Measures of South Carolina's Estuarine Habitat Quality

A primary goal of SCECAP is to combine integrated measures of water quality, sediment quality, and biological condition into an overall measure of habitat quality at each site and for the entire coastal zone of South Carolina. Multi-metric measures provide a more reliable assessment than any single measure or group of measures representing only one component of the habitat. For example, poor or fair water quality based on state standards or historical data may not result in any clear evidence of impaired biotic communities. Many of the state's water quality standards are intentionally conservative to be protective and some contravention of these conditions are not severe enough to represent impairment. Similarly, fair or poor sediment quality may not result in degraded biotic condition because the organisms are either not directly exposed to the sediments (e.g., phytoplankton, fish) or because the contaminants are not readily bioavailable to the animals. When two or more of the three measures (i.e., water quality, sediment quality, or biotic condition) are fair or poor, there is increased certainty that the habitat may be limiting. This "triad" approach to measuring overall habitat quality has been or is being used in many other monitoring programs assessing the health of coastal environments (e.g., Chapman, 1990; Chapman *et al.*, 1991; USEPA, 2001).

The overall index of habitat quality was modified for the 2001-2002 survey to better reflect possible impairment of coastal habitats. In the 1999-2000 survey, a site had to have poor scores for all three components (i.e., water, sediment, biota) in order for overall habitat quality to be scored as poor. None of the sites sampled in the first four years of this program met these criteria, even in areas with known problems. This indicates that these criteria may be too restrictive. Additionally, for the 2001-2002 assessment, the final score of each component was adjusted to contribute equal weight to the overall habitat condition score (see Figure 3.6.1). This eliminated the problem of unequal score values representing the same condition level (i.e., good, fair, or poor) for the different components, which occurred with the original index used for the 1999-2000 survey period. Using the new scoring process, a site scores as poor if two or more of the habitat quality components score as poor, or if one component scores as poor and the other two are fair. A site is considered to be fair if two or more of the habitat quality components are fair or only one component is poor. An example of the scoring process is shown in Figure 3.6.1 for station RT01654.

Using the revised scoring approach, approximately 2% of South Carolina's open water and none of the tidal creek habitats coded as poor in overall habitat quality (Figure 3.6.2). An additional 17% of open

Overall Habitat Quality Scoring Process

Water Quality Score	Sediment Quality Score	Benthic Index Score		Adjusted Score	Range of Possible Adjusted Scores When Averaged
> 4	≥ 4	≥ 3	Good	5	4.3 - 5.0
> 3 - ≤ 4	2 - 3	2 - 2.5	Marginal	3	3.0 - 3.7
≤ 3	1	≤ 1.5	Poor	1	1.0 - 2.3

Station RT01654 Example

5	3	1	9.0 / 3 =	3.0	Adjusted Score

Figure 3.6.1. Summary of threshold values and scoring process used to obtain the overall habitat quality score. Station RT01654 is used as an example of how the scoring process was applied using the revised scoring approach.

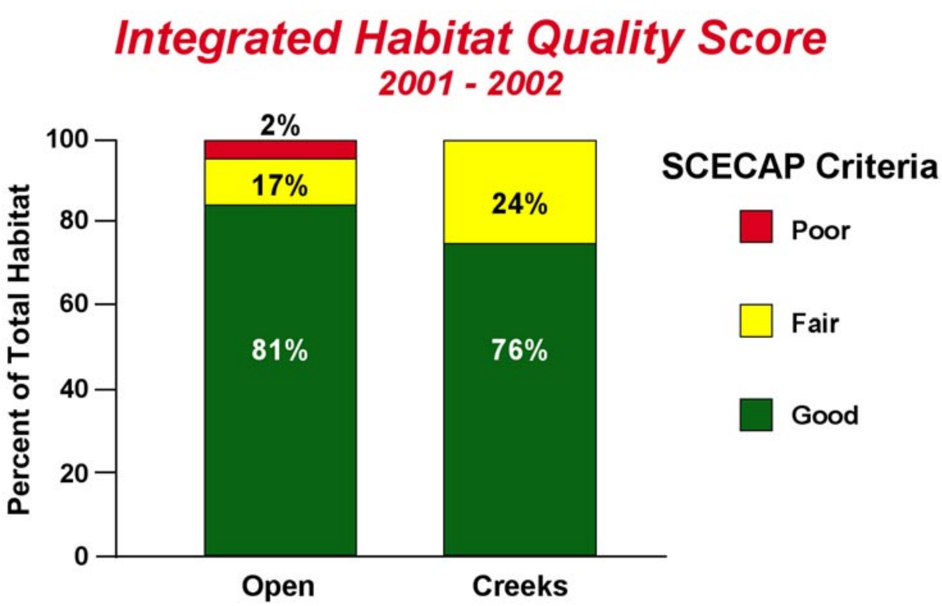


Figure 3.6.2. Estimated percentage of South Carolina's estuarine tidal creek and open water habitat that is in good, fair, or poor condition using an average of water, sediment, and biological quality scores developed for the SCECAP monitoring effort.

water habitat and 24% of tidal creek habitat coded as fair in overall habitat quality. The overall habitat quality scores for each of the stations sampled in 2001 and 2002 are presented in Appendix 2. In addition, the integrated water and sediment quality scores and B-IBI scores are presented, along with the scores for each component parameter. Scores and component parameters are color coded red for poor, yellow for fair, and green for good.

The higher percentage of tidal creek habitat that coded as fair compared to open water habitats is likely due to the fact that these shallow wetland habitats are often the first areas impacted by anthropogenic stresses from upland development (Holland *et al.,* 1997; Sanger *et al*. 1999a,b; Van Dolah *et al.,* 2000). For example, a larger percentage of the tidal creek habitat coded as fair or poor for contaminants and toxicity tests compared to the open water habitat (see the sediment quality section). Chemical contaminants are adsorbed to small particles of sediment, so these results may, in part, be due to the greater percentage of tidal creek habitats with muddy sediment composition when compared to open water habitats (Figure 3.3.1). Tidal creeks are also more stressful habitats with respect to water quality when compared to open water habitats (see the water quality section). Since the thresholds that are currently being used for many of the water quality parameters were developed from data collected primarily from open water

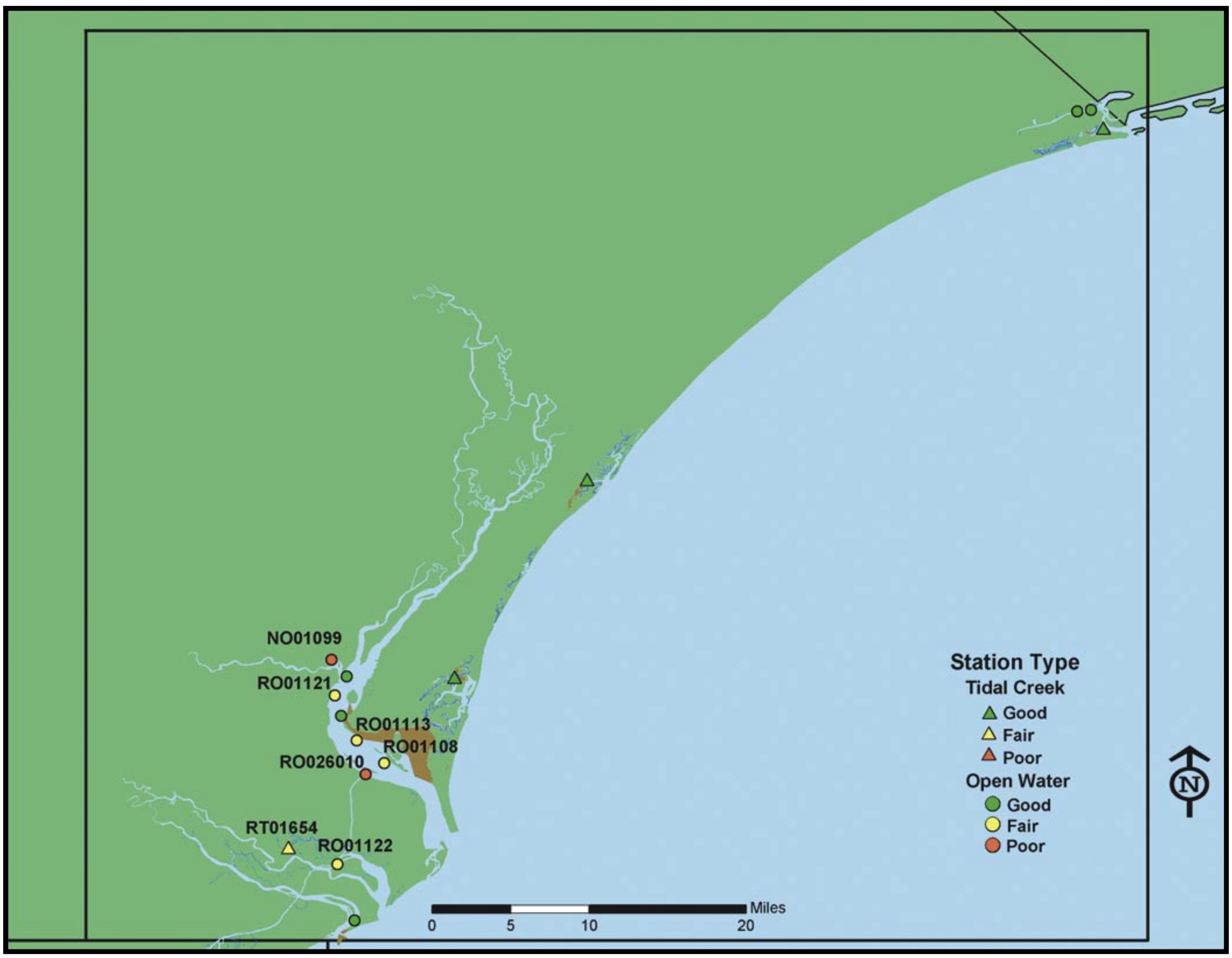


Figure 3.6.3. Distribution of open water and tidal creek stations sampled in the northern portion of the state during 2001-2002 that had an integrated habitat quality score of "good", "fair", or "poor" based on an integrated measure of water quality, sediment quality, and biotic condition.

habitats, these thresholds may be overly restrictive in some cases where naturally stressful conditions occur in tidal creeks.

The 2001-2002 array of stations is presented in Figure 3.6.3 – 3.6.5 with each station color-coded based on the overall integrated habitat quality score (Appendix 2). Station codes are indicated on the maps only for those sites that scored as fair or poor.

In the northern portion of the state, one of the 14 randomly located stations sampled in 2001-2002 coded as poor in overall habitat quality, five coded as fair in overall quality, and the remaining eight stations had good overall habitat quality (Figure 3.6.3). Station (RO026010) had the poor overall habitat quality score, and was located in Winyah Bay near the mouth of the intracoastal waterway (ICWW). The site had fair water quality and poor sediment quality and benthic community condition. This site was located near dredge disposal areas, which may have contributed to the poor habitat condition. Another non-random station located in the Georgetown Harbor turning basin also had poor overall habitat quality (see next section). Three of the sites that coded as fair were located in the Winyah Bay estuarine system and the other two were located in the Santee River system. The sites in Winyah Bay generally had good to fair water quality, fair sediment quality, and good to poor benthic community condition. The sites in

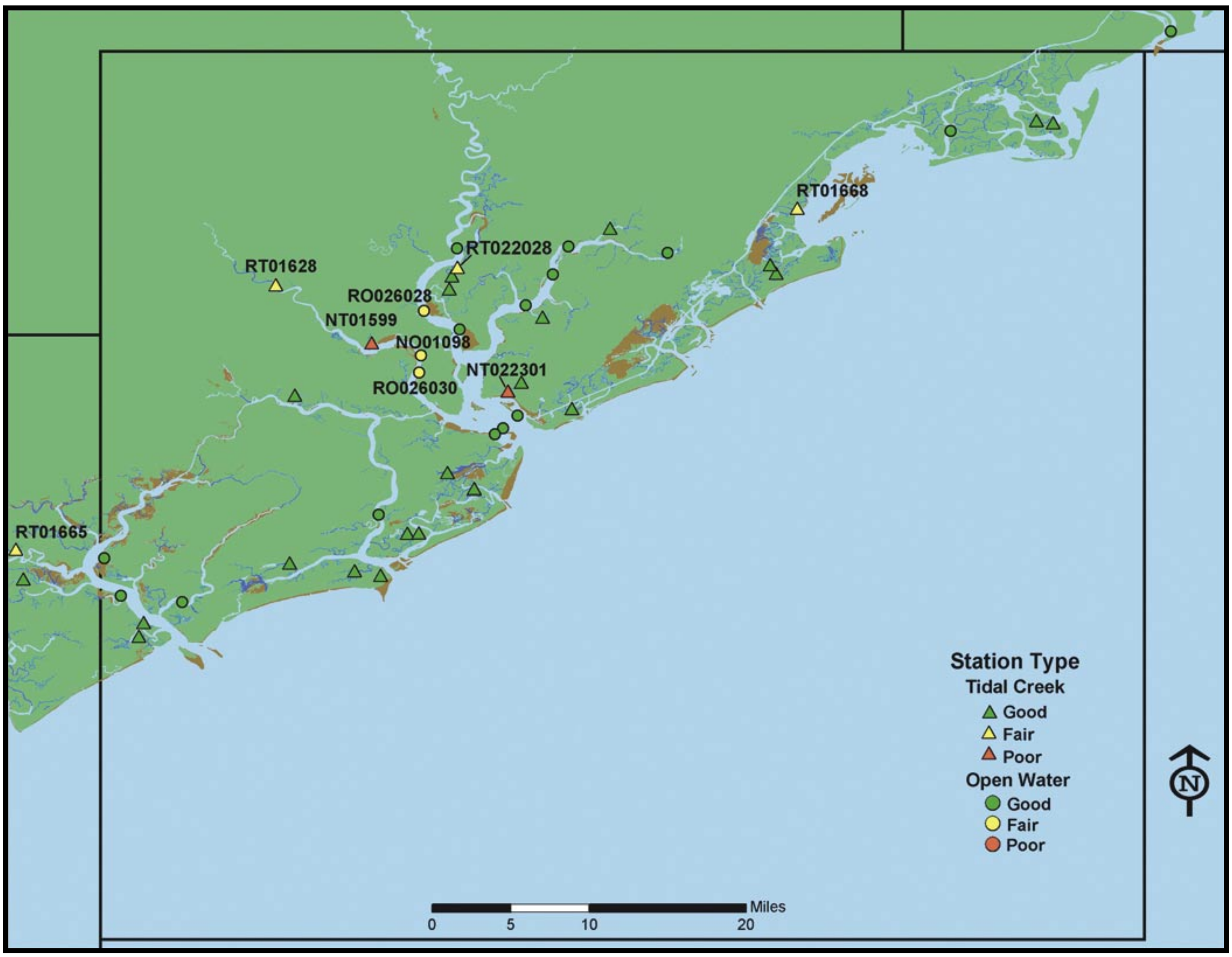


Figure 3.6.4. Distribution of open water and tidal creek stations sampled in the central portion of the state during 2001-2002 that had an integrated habitat quality score of "good", "fair", or "poor" based on an integrated measure of water quality, sediment quality, and biotic condition.

the Santee River system generally had good water quality, but only fair sediment quality, and fair to poor benthic community condition.

Of the 36 randomly located sites sampled in the central portion of the state's coastal zone, five ranked as fair in overall quality, and the rest had good overall habitat quality (Figure 3.6.4). All except one of the fair sites were located in the Charleston Harbor estuary, with three of those sites located in proximity to industrial areas in either the Cooper or Ashley Rivers. Water quality at these sites ranged from good to fair, sediment quality was consistently in the fair range, and benthic community condition ranged from good to fair (Appendix 2). Three of the five non-random sites sampled in this estuary (lower portion of Shem Creek, Ashley River in Brickyard Creek, and near the Columbia Nitrogen Plant) had fair or poor overall habitat quality (see next section).

In the southern portion of the state, 12 of the 66 randomly selected sites were fair in overall habitat quality, and the remaining sites had good overall habitat quality (Figure 3.6.5). Nine of these sites were located in tidal creeks. Two tidal creek sites (RT01603 located in the Old Chehaw River and RT022005 located in Fishing Creek off the Dawhoo River cut) had poor water quality, but fair to good sediment quality and benthic community condition scores. One site (RT02153 in the upper Okatie River)

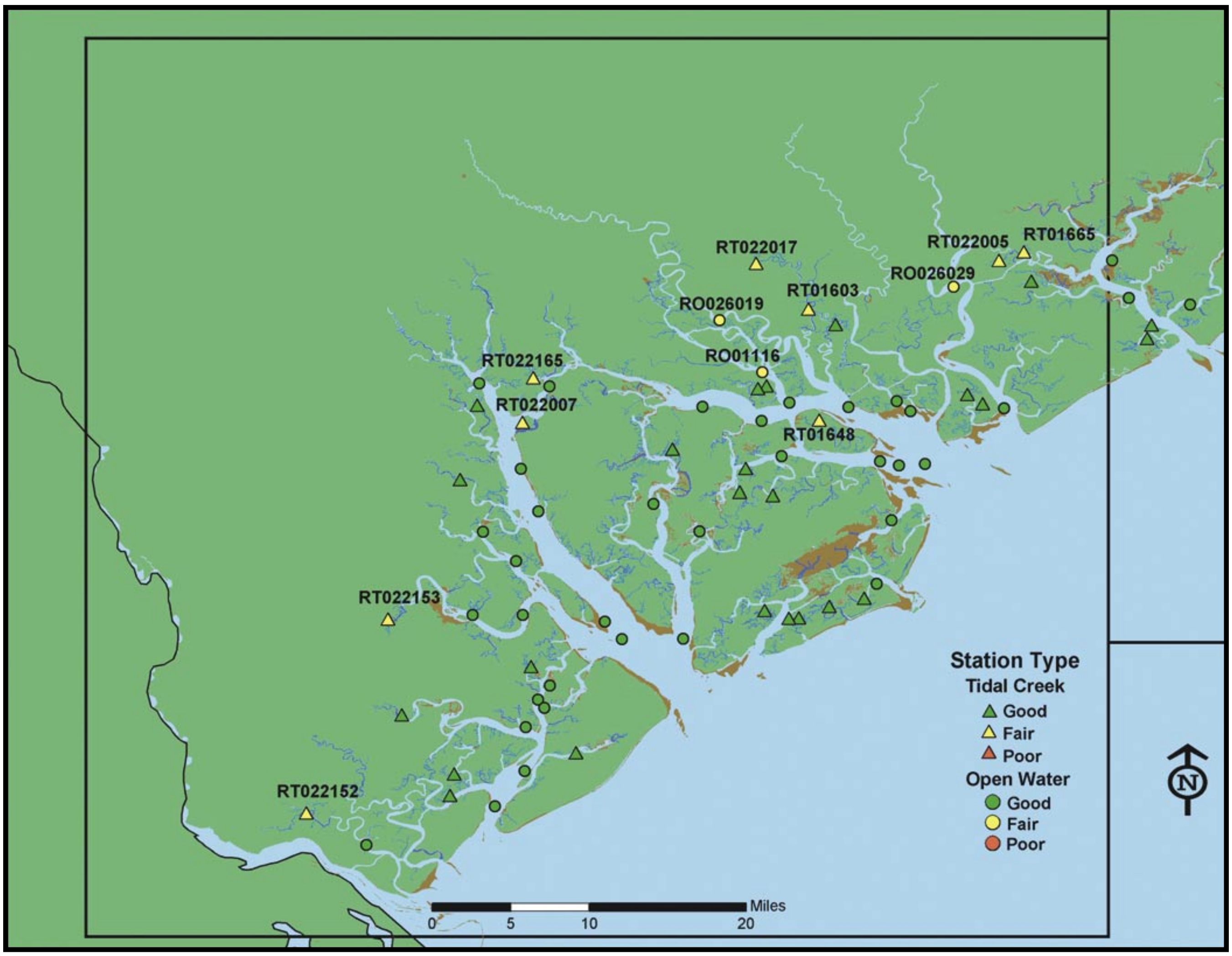


Figure 3.6.5. Distribution of open water and tidal creek stations sampled in the southern portion of the state during 2001-2002 that had an integrated habitat quality score of "good", "fair", or "poor" based on an integrated measure of water quality, sediment quality, and biotic condition.

had poor biotic condition but good water and sediment quality. None of the other sites sampled in this region had poor scores for any of the three habitat quality components. This may reflect the pattern of higher urban and industrial land use in the Winyah Bay and Charleston Harbor area relative to the southern part of the state that does not have as much urban and industrial development.

As discussed earlier in the report, the parameters used to generate the integrated water quality scores and the overall calculation of the integrated habitat quality score for the 2001-2002 survey were updated from the methods used in the 1999-2000 survey (Van Dolah *et al*., 2002a). Therefore, a direct comparison among survey periods of the number of stations with overall integrated habitat quality classified as poor or fair must involve the application of the 2001-2002 approach (Figure 3.6.1) on the earlier 1999-2000 datasets. Using this new approach, we did not see a major change in the percentage of the state's estuarine habitat that was considered to be good, fair, and poor over the four-year period sampled to date (Figure 3.6.6). As noted earlier in the report, very little change was observed over the four-year period with respect to the water quality score (Figure 3.2.15), although a general trend of increasing habitat coded as fair was observed with respect to sediment quality (Figure 3.3.9) and benthic community condition (Figure 3.4.6). During this time period, South Carolina has experienced an unusual drought period that would have reduced the amount of runoff from upland to wetland habitats, and undoubtedly influenced many of the individual measures collected. Conditions during years with more normal rainfall may change the overall assessment of the state's coastal condition.

3.7 Non-random Stations

During the 2001-2002 sampling period, a subset of seven non-random stations were sampled in addition to the random array of 115 stations. Three of these stations (NO01098, NO01099, and NO026302) were collected in open water habitats, and the remaining four stations were collected in tidal creek habitats (NT01598, NT01599, NT01651, and NT022301). With the exception of NT01651, non-random stations were selected due to their location in areas that were suspected to be impacted by land use activities. Station NT01651 was erroneously sampled outside of the targeted creek, and was changed to a non-random designation.

As discussed earlier in the text, non-randomly located stations were not used to estimate the proportion of South Carolina's coastal habitat that coded as good, fair, or poor condition with respect to various measures, nor were they used to generate

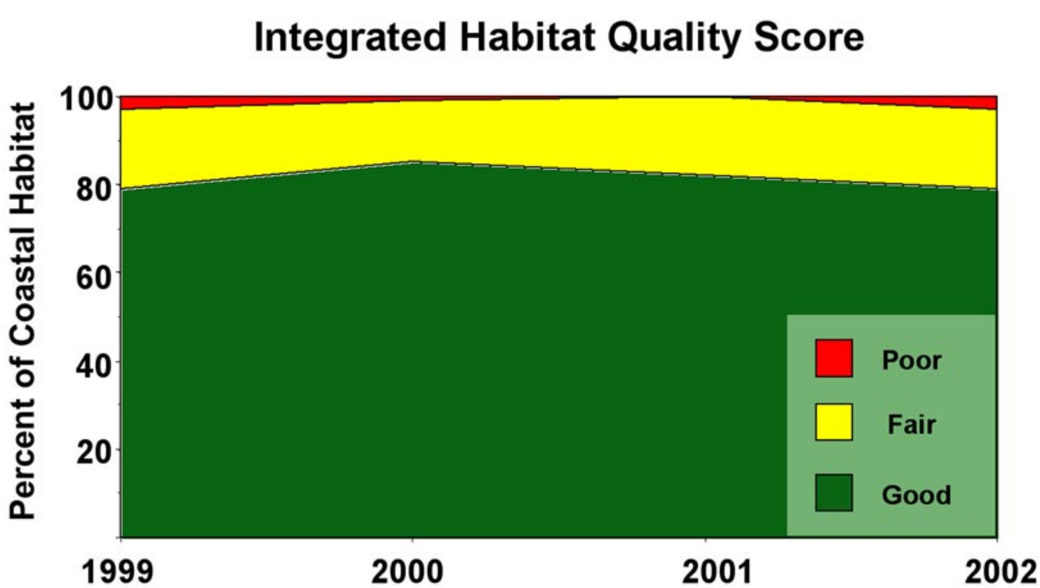


Figure 3.6.6. The proportion of South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated habitat quality score when tidal creek and open water habitats are combined and compared on an annual basis.

mean values for various parameters measured (data online). However, these non-random stations provide important information on areas within the state where degraded conditions are suspected to exist. These data can be used to further develop threshold values for integrated measures, and provide insight on the response and interaction of various measures in impacted areas.

Among the four non-random stations located in tidal creeks, two had a good overall habitat quality score, and the other two had poor habitat quality (Appendix 2, Figures 3.6.3 – 3.6.4). Station NT01651, the station that was not targeted in a potentially degraded location, but rather sampled by error in the wrong location, scored good for water quality, sediment quality, and biotic condition. The other tidal creek station (NT01598) that had good overall habitat quality was located in the central region of the state in the middle reach of Shem Creek, and also had good scores for water quality, sediment quality, and biotic condition. The two non-random tidal creek stations with poor overall habitat quality were located in the central region of the state in Brickyard Creek (NT01599) and near the mouth of Shem Creek adjacent to commercial docks and other upland development (NT022301). The station in Brickyard Creek had poor water quality and fair sediment quality and biotic condition. The station located in Shem Creek had fair water quality, but poor sediment quality and biotic condition.

Two of the three non-random stations located in open water habitats were located in the central region of the state (Ashley River, NO011098; Wando River, NO026302), with the remaining station located in the northern region of the state (Georgetown Harbor, NO011099). The Ashley River station had a fair integrated habitat quality score, and was considered to have good water quality and biotic condition, but a poor sediment quality score. This station was located near both the Columbia Nitrogen Plant and the Koppers Plant, both of which are EPA Superfund (CERCLA) sites. The station located in the Wando River was located near Deyten's Shipyard. This site had good overall habitat quality, with good water quality and biotic condition scores, and fair sediment quality. The station in Georgetown Harbor had poor integrated habitat quality, with poor water quality and biotic condition and fair sediment quality. This area was also found to be fair in quality during the 1999-2000 survey based on the earlier approach for calculating overall integrated habitat quality scores (Van Dolah *et al*., 2002a).

3.8 Summary

The detailed information on water quality, sediment quality, and biotic condition collected during 2001-2002, in addition to previous and future SCECAP sampling efforts, provides a valuable database on the current status of South Carolina's tidal creek and open water habitats. The program samples areas with no clear evidence of anthropogenic input, as well as areas near industrial and residential development. Through the addition of non-random stations, areas that are of particular concern can be evaluated in relation to a larger state-wide database. The SCECAP database also provides a valuable measure of the proportion of the state's subtidal coastal habitat that is good, fair, or poor with respect to the various measures collected. Moreover, the quality of South Carolina's coastal habitats can be tracked over time, and can be compared to ongoing assessments in neighboring states being conducted in partnership with the EPA's National Coastal Assessment Program.

The SCECAP program will continue to produce summaries of South Carolina's coastal condition every two years to evaluate change over time, pending funding for this program. Future sampling will also provide an opportunity to statistically evaluate conditions within some of the larger drainage basins, such as Winyah Bay, Charleston Harbor, Port Royal Sound, or within specific areas of interest such as Georgetown County, Charleston County, Beaufort County, etc. Defining criteria for good, fair, and poor conditions with respect to water quality, sediment quality, and biological measures is an evolving process, and will continue to be re-evaluated as the SCECAP dataset continues to grow. Likewise, the threshold values used to develop the integrated measures may be revisited in the future in an effort to more accurately classify degraded and healthy habitats.

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Appendix 1. Summary of station locations and dates sampled in 2001 and 2002. Open water sites are designated as RO (random open water site) or NO (non-random open water site), and tidal creek sites are designated as RT (random tidal creek site) or NT (non-random tidal creek site). Development codes: NDV = no development visible; R < 1 = residential development less than 1 km away; R > 1 = residential development greater than 1 km away; I < 1 = industrial development less than 1 km away; I > 1 = industrial development located greater than 1 km away.

SCECAP 2001 Water Quality
Station Information -- Open Water

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code	Approximate Location
RO01108	Open	33.27009	79.24096	2.1	7/17/01	Georgetown	NDV	Lower Winyah Bay; shipping channel by marker 23
RO01109	Open	32.92346	79.93020	4.9	6/27/01	Berkeley	R>1	Cooper River above Goose Creek
RO01110	Open	32.44857	80.43067	5.0	8/22/01	Beaufort	R>1	St. Helena Sound
RO01111	Open	32.40533	80.78914	8.2	8/14/01	Beaufort	R>1	Broad River above Hwy 170 bridge
RO01112	Open	32.23079	80.78944	5.8	7/11/01	Beaufort	R<1	Mackay Creek just above Hwy 278
RO01113	Open	33.29078	79.26639	8.5	7/17/01	Georgetown	I>1	Marker 26 in Winyah Bay
RO01114	Open	32.91942	79.73521	0.9	7/25/01	Charleston	R>1	Paradise Landing in Wando River
RO01115	Open	32.45101	80.47250	10.4	8/22/01	Beaufort	R>1	St. Helena Sound
RO01116	Open	32.53382	80.58137	4.9	8/21/01	Beaufort	R>1	Bull River above St. Helena Sound
RO01117	Open	32.24375	80.77832	2.1	7/11/01	Beaufort	R>1	Mackay Creek beside Pinckney Is.
RO01121	Open	33.33272	79.28662	2.4	7/17/01	Georgetown	R<1	West of Rabbit Island in Winyah Bay
RO01122	Open	33.17620	79.28421	1.8	7/24/01	Georgetown	NDV	ICWW North Santee; Minim Is.
RO01123	Open	32.50039	80.35751	7.6	8/14/01	Colleton	R>1	Edisto River Mouth near Pine Island
RO01124	Open	32.48871	80.58211	6.1	8/21/01	Beaufort	R<1	Coosaw River
RO01125	Open	32.30929	80.84986	1.0	7/11/01	Beaufort	R>1	Colleton River at Callawassie Creek
RO01129	Open	32.75694	79.88757	7.6	6/26/01	Charleston	R<1	Charleston Harbor near Fort Johnson
RO01130	Open	33.87242	78.59882	2.1	7/2/01	Horry	R<1	ICWW near Little River
RO01131	Open	32.63712	80.25724	1.0	8/7/01	Charleston	R>1	Wadmalaw Sound below Bear's Bluff
RO01132	Open	32.52053	80.77885	4.3	8/15/01	Beaufort	R<1	Whale Branch
RO01133	Open	32.30325	80.72738	12.5	7/31/01	Beaufort	R<1	Mouth of Broad River at south tip of Daws Island
RO01144	Open	32.67730	80.00293	2.4	8/8/01	Charleston	R<1	Stono River just above Abbapoola Creek
RO01145	Open	32.59644	80.18507	4.9	8/7/01	Charleston	R<1	Bohicket Creek
RO01146	Open	32.35915	80.80954	3.0	7/11/01	Beaufort	R>1	Chechesee Creek
RO01147	Open	32.38681	80.63964	4.6	7/31/01	Beaufort	R<1	Cowen Creek tributary
RO01148	Open	32.39712	80.46185	2.0	8/2/01	Beaufort	R>1	Harbor River behind Harbor Island
RO01161	Open	33.31382	79.28106	3.0	7/17/01	Georgetown	I>1	Winyah Bay near marker 32 just below Rabbit Island
RO01162	Open	32.87078	79.86659	4.9	8/15/01	Berkeley	R>1	Wando River near Beresford Creek
RO01163	Open	32.44715	80.45494	9.0	8/22/01	Beaufort	R>1	St. Helena Sound
RO01164	Open	32.45573	80.56372	2.4	7/31/01	Beaufort	R>1	Morgan River
RO01165	Open	32.16461	80.80172	3.5	7/10/01	Beaufort	R<1	Calibogue Sound near Broad Creek
NO01098	Open	32.82421	79.96382	1.2	6/26/01	Charleston	I<1	Ashley River near old Columbia Nitrogen Plant
NO01099	Open	33.36577	79.28994	8.5	7/25/01	Georgetown	I>1	Georgetown Harbor in turning basin

SCECAP 2001 Water Quality
Station Information -- Tidal Creeks

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code	Approximate Location
RT01602	Creek	32.21660	80.91584	4.9	7/10/01	Beaufort	R<1	Upper May River
RT01603	Creek	32.59202	80.53874	3.7	8/21/01	Colleton	NDV	Old Chehaw River
RT01604	Creek	32.43414	80.86175	1.8	8/14/01	Jasper	R<1	Euhaw Creek
RT01606	Creek	33.03987	79.37805	3.0	7/24/01	Charleston	NDV	Cape Romain; Devil's Den Creek
RT01619	Creek	32.31344	80.57936	2.1	8/1/01	Beaufort	R>1	Creek off Trenchard's Inlet
RT01624	Creek	32.31730	80.51946	4.9	8/1/01	Beaufort	NDV	Creek off Trenchard's Inlet
RT01625	Creek	32.51317	80.39134	2.7	8/14/01	Colleton	NDV	Fish Creek between Otter and Pine Is.
RT01628	Creek	32.88975	80.09810	3.4	6/26/01	Dorchester	R>1	Ashley River above Magnolia Gardens
RT01633	Creek	32.89796	79.93513	5.8	6/27/01	Berkeley	I>1	Clouter Creek off Cooper River
RT01642	Creek	32.62105	80.00113	2.1	8/8/01	Charleston	NDV	Kiawah Island; eastern tip
RT01643	Creek	32.52092	80.57780	6.1	8/21/01	Beaufort	NDV	Creek off Bull River above St. Helena Sound
RT01644	Creek	32.71570	79.93916	1.5	6/26/01	Charleston	R<1	Clark's Sound
RT01645	Creek	33.34942	79.17596	5.2	7/18/01	Georgetown	NDV	North Inlet; Upper Old Man Creek
RT01646	Creek	32.16210	80.86715	2.1	7/10/01	Beaufort	R<1	Tributary of Bull Creek behind Hilton Head
RT01647	Creek	32.63268	80.08536	1.5	8/8/01	Charleston	R<1	Mullet Hall Creek off Kiawah River
RT01648	Creek	32.48918	80.52880	4.0	8/22/01	Beaufort	NDV	Morgan Island
RT01649	Creek	32.66012	79.97645	6.0	8/8/01	Charleston	R>1	Robbins Creek behind Folly Island
RT01650	Creek	33.85712	78.57478	1.5	7/2/01	Horry	R>1	Creek behind Waites Island
RT01652	Creek	32.56488	80.22507	3.6	8/7/01	Charleston	R>1	Tributary off Ocella Creek, Near Botany Bay Island
RT01653	Creek	32.41968	80.57188	2.4	8/21/01	Beaufort	R<1	Tributary off Jenkins Creek, on St Helena Island
RT01654	Creek	33.19171	79.32968	2.1	7/24/01	Georgetown	NDV	West confluence of Minim Creek, North Santee River
RT01655	Creek	33.53176	79.05311	1.2	7/18/01	Georgetown	R<1	Tributary of Murrell's Inlet
RT01664	Creek	32.32470	80.48732	3.7	8/2/01	Beaufort	R<1	Creek behind Fripp Island, near marina
RT01665	Creek	32.64526	80.33919	0.9	8/7/01	Charleston	NDV	Dawho River
RT01668	Creek	32.96054	79.61518	2.4	7/25/01	Charleston	R>1	Vanderhorst Creek, Bull Bay
NT01598	Creek	32.79947	79.87076	0.9	6/27/01	Charleston	R<1	Shem Creek in Charleston Harbor
NT01599	Creek	32.83600	80.00938	1.2	6/27/01	Charleston	I<1	Brickyard Creek on Ashley River
NT01651	Creek	32.14201	80.87108	2.1	7/10/01	Beaufort	R<1	Creek off Cooper River behind Daufuskie Island

SCECAP 2002 Water Quality
Station Information -- Open Water

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code	Approximate Location
RO026001	Open	32.50120	80.50169	17.6	6/18/02	Colleton	NDV	Coosaw River near mouth of Combahee River
RO026002	Open	32.20525	80.80085	2.4	8/7/02	Beaufort	R>1	May River near Calibogue Sound
RO026003	Open	32.41230	80.68226	5.5	7/9/02	Beaufort	R<1	Beaufort River near Spanish Point
RO026004	Open	33.12431	79.26868	1.2	7/16/02	Georgetown	NDV	Mouth of South Santee River
RO026005	Open	32.50550	80.55633	7.9	6/18/02	Beaufort	R>1	Coosaw River near mouth of Bull River
RO026006	Open	32.33804	80.47536	5.5	8/21/02	Beaufort	R<1	Old House Creek near Fripp Inlet
RO026007	Open	32.50178	80.63675	3.4	6/19/02	Beaufort	R<1	Coosaw River south of Chisolm Island
RO026008	Open	33.03231	79.47299	3.4	7/17/02	Charleston	NDV	Five Fathom Creek near Bull Bay
RO026009	Open	32.13219	80.82913	17.6	8/6/02	Beaufort	R>1	Calibogue Sound near mouth of Cooper River
RO026010	Open	33.25959	79.25809	3.4	7/17/02	Georgetown	NDV	Winyah Bay near mouth of Minim Creek
RO026011	Open	32.09641	80.94844	5.8	8/6/02	Jasper	I>1	Wright River north of Mud River
RO026012	Open	33.35002	79.27575	4.3	7/17/02	Georgetown	R>1	Winyah Bay near mouth of Sampit River
RO026013	Open	32.60241	80.24170	3.4	6/25/02	Charleston	R<1	West Bank Creek near North Edisto River
RO026014	Open	32.89944	79.84164	7.0	8/13/02	Berkeley	R<1	Wando River near Juba Island
RO026016	Open	32.75144	79.89511	0.6	7/31/02	Charleston	R<1	Charleston Harbor east of Ft. Johnson
RO026017	Open	32.44410	80.80507	4.3	7/8/02	Beaufort	NDV	Broad River below Whale Branch
RO026018	Open	32.28675	80.71152	11.3	7/23/02	Beaufort	R>1	Broad River near Daws Island
RO026019	Open	32.58192	80.62095	6.1	8/20/02	Colleton	NDV	Combahee River near Williman Islands
RO026020	Open	32.22310	80.78366	3.0	8/7/02	Beaufort	R<1	Skull Creek behind Hilton Head
RO026021	Open	32.38642	80.84018	2.7	7/23/02	Beaufort	R>1	Chechessee River NW of Lemon Island
RO026022	Open	32.28715	80.65486	10.4	7/9/02	Beaufort	R>1	Mouth of Beaufort River
RO026023	Open	32.30939	80.80363	6.4	7/23/02	Beaufort	R<1	Colleton River near Daws Island
RO026024	Open	33.87390	78.58598	2.7	7/16/02	Horry	R<1	Little River in the ICWW
RO026025	Open	32.50694	80.45691	1.8	6/26/02	Colleton	NDV	Rock Creek near Ashe Island
RO026026	Open	32.76846	79.87434	6.1	7/31/02	Charleston	R>1	Crab Bank in Charleston Harbor
RO026027	Open	32.49761	80.44432	4.0	6/26/02	Colleton	NDV	Rock Creek near Hutchinson Island
RO026028	Open	32.96541	79.96100	13.4	8/13/02	Charleston	I<1	Cooper River near old Navy base
RO026029	Open	32.61281	80.40415	2.7	6/26/02	Colleton	R>1	Upper South Edisto River North of Sampson Island
RO026030	Open	32.80832	79.96541	1.5	7/31/02	Charleston	I<1	Ashley River below Koppers Creek
RO026151	Open	32.52328	80.84390	1.2	7/10/02	Jasper	R>1	Broad River above Whale Branch
RO026290	Open	32.84843	79.92776	8.2	8/27/02	Berkeley	I<1	Cooper River across from NOAA Pier Romeo
NO026302	Open	32.92522	79.82712	7.0	8/27/02	Berkeley	I<1	Deyten's Shipyard on Wando River

SCECAP 2002 Water Quality
Station Information -- Tidal Creeks

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code	Approximate Location
RT022002	Creek	32.30647	80.54790	4.6	8/21/02	Beaufort	R<1	Capers Creek off Trenchard's Inlet
RT022004	Creek	32.90035	79.63480	2.1	8/14/02	Charleston	NDV	Back Creek behind Bull Island
RT022005	Creek	32.63734	80.36210	6.7	6/25/02	Charleston	NDV	Fishing Creek off Dawhoo Cut
RT022006	Creek	32.77504	79.82408	2.7	7/31/02	Charleston	R<1	Narrows Creek behind Sullivan's Island
RT022007	Creek	32.48720	80.80390	2.1	7/10/02	Beaufort	NDV	Cotton Island in the mouth of Whale Branch
RT022008	Creek	32.70097	79.91453	1.8	7/30/02	Charleston	R>1	Second Sister Creek off Lighthouse Inlet
RT022009	Creek	32.50321	80.84580	2.4	7/10/02	Jasper	R<1	East Branch of Boyd's Creek off Beaufort River
RT022013	Creek	32.46236	80.66489	0.9	7/9/02	Beaufort	R<1	Broomfield Creek off Beaufort River
RT022015	Creek	32.51859	80.58552	2.1	6/19/02	Beaufort	NDV	Oak Island Creek near Bull River
RT022016	Creek	33.04177	79.39329	3.4	7/17/02	Charleston	NDV	Devil's Den Creek in Cape Romain
RT022017	Creek	32.63446	80.58727	2.4	6/19/02	Colleton	NDV	Old Chehaw River near Hwy 162
RT022019	Creek	32.50454	80.37736	3.4	6/26/02	Colleton	NDV	Fish Creek near Otter Island
RT022021	Creek	32.61791	80.33235	1.5	6/25/02	Charleston	R<1	Sand Creek off of Steamboat Creek
RT022022	Creek	32.18158	80.75424	2.1	8/6/02	Beaufort	R<1	Broad Creek in Hilton Head
RT022027	Creek	32.44443	80.59708	1.0	6/18/02	Beaufort	R<1	Sparrow Nest Creek off Morgan River
RT022028	Creek	32.90585	79.92989	5.5	8/13/02	Berkeley	I>1	Yellow House Creek off Cooper River
RT022030	Creek	32.94194	79.78838	1.2	8/14/02	Berkeley	NDV	Old House Creek off Guerin Creek
RT022152	Creek	32.12601	81.00413	4.6	8/6/02	Jasper	I>1	Upper Wright River below Turn Bridge Boat Ramp
RT022153	Creek	32.30561	80.92840	1.2	7/23/02	Beaufort	R<1	Upper Okatie River
RT022154	Creek	32.78738	80.08080	1.8	7/30/02	Charleston	R>1	Creek off Stono River near Clemson Ag Station
RT022155	Creek	32.62523	80.02534	3.7	7/30/02	Charleston	R<1	Bass Creek behind Kiawah Island
RT022156	Creek	32.30610	80.55713	4.0	8/21/02	Beaufort	R<1	Capers Creek off Trenchard's Inlet
RT022157	Creek	32.42277	80.60264	4.0	6/18/02	Beaufort	R<1	Warsaw Island in Jenkins Creek
RT022160	Creek	32.26160	80.79589	3.7	8/7/02	Beaufort	R>1	Mackay Creek behind Hilton Head Island
RT022162	Creek	32.85979	79.85099	2.7	8/13/02	Charleston	R>1	Foster Creek off Wando River
RT022164	Creek	32.90837	79.64002	2.0	8/14/02	Charleston	NDV	Bull Narrows behind Bull Island
RT022165	Creek	32.52839	80.79371	1.8	7/10/02	Beaufort	NDV	Haulover Creek off Whale Branch
RT022167	Creek	32.57779	80.51369	2.7	6/19/02	Colleton	NDV	New Chehaw River NE of Boulder Island
RT022170	Creek	32.66034	79.96557	1.5	7/30/02	Charleston	R>1	Creek between Folly River and Robbins Creek
RT022171	Creek	32.57739	80.22091	0.9	6/25/02	Charleston	NDV	Creek at Point of Pines on North Edisto
RT022282	Creek	32.88581	79.93765	5.8	8/27/02	Berkeley	R<1	Clouter Creek off Cooper River
NT022301	Creek	32.79128	79.88297	5.2	8/27/02	Charleston	R<1	Shem Creek below Coleman Blvd Bridge

Appendix 2. Summary of integrated measures of water quality, sediment quality, and biological condition (based on the Benthic Index of Biological Integrity), and the overall integrated measure of habitat quality using a combination of the three measures. Station location information is also provided. Scores coding as green represent good conditions, yellow represents fair conditions, and red indicates poor conditions. The actual values of the integrated scores are also shown to allow the reader to see where the values fall within the above general coding criteria. See text for further details on ranges of values representing good, fair, and poor for each integrated score.

SCECAP 2001 -- Open Water
Integrated Assessment

Station	Water Quality							Sediment Quality			Biological Condition	Overall	County	Location
	Dissolved Oxygen	Fecal Coliform	pH	Total Nitrogen	Total Phosphorus	Chlorophyll-a	Integrated Score	Toxicity	Contaminants	Integrated Score	Benthic IBI	Integrated Score		
RO01108							5			3	1	3.0	Georgetown	Lower Winyah Bay; shipping channel by marker 23
RO01109							5			5	5	5.0	Berkeley	Cooper River above Goose Creek
RO01110							5			5	3	4.3	Beaufort	St. Helena Sound
RO01111							5			5	5	5.0	Beaufort	Broad River above Hwy 170 bridge
RO01112							5			5	5	5.0	Beaufort	Mackay Creek just above Hwy 278
RO01113							3			3	5	3.7	Georgetown	Marker 26 in Winyah Bay
RO01114							5			5	3	4.3	Charleston	Paradise Landing in Wando River
RO01115							5			5	3	4.3	Beaufort	St. Helena Sound
RO01116							3			5	3	3.7	Beaufort	Bull River above St. Helena Sound
RO01117							5			5	5	5.0	Beaufort	Mackay Creek beside Pinckney Is.
RO01121							3			3	5	3.7	Georgetown	West of Rabbit Island in Winyah Bay
RO01122							5			3	3	3.7	Georgetown	ICWW North Santee; Minim Is.
RO01123							5			5	5	5.0	Colleton	Edisto River Mouth near Pine Island
RO01124							5			5	5	5.0	Beaufort	Coosaw River
RO01125							5			3	5	4.3	Beaufort	Colleton River at Callawassie Creek
RO01129							5			5	5	5.0	Charleston	Charleston Harbor near Fort Johnson
RO01130							5			5	5	5.0	Horry	ICWW near Little River
RO01131							5			3	5	4.3	Charleston	Wadmalaw Sound below Bear's Bluff
RO01132							5			3	5	4.3	Beaufort	Whale Branch
RO01133							5			5	5	5.0	Beaufort	Mouth of Broad River at south tip of Daws Island
RO01144							5			5	5	5.0	Charleston	Stono River just above Abbapoola Creek
RO01145							5			5	5	5.0	Charleston	Bohicket Creek
RO01146							5			5	5	5.0	Beaufort	Chechesee Creek
RO01147							5			3	5	4.3	Beaufort	Cowen Creek tributary
RO01148							5			5	5	5.0	Beaufort	Harbor River behind Harbor Island
RO01161							5			3	5	4.3	Georgetown	Winyah Bay near marker 32 just below Rabbit Island
RO01162							5			5	5	5.0	Berkeley	Wando River near Beresford Creek
RO01163							5			5	5	5.0	Beaufort	St. Helena Sound
RO01164							5			5	5	5.0	Beaufort	Morgan River
RO01165							5			5	5	5.0	Beaufort	Calibogue Sound near Broad Creek
NO01098							5			1	5	3.7	Charleston	Ashley River near old Columbia Nitrogen Plant
NO01099							1			3	1	1.7	Georgetown	Georgetown Harbor in turning basin

SCECAP 2001 -- Tidal Creeks
Integrated Assessment

Station	Water Quality: Dissolved Oxygen	Fecal Coliform	pH	Total Nitrogen	Total Phosphorus	Chlorophyll-a	Integrated Score	Sediment Quality: Toxicity	Contaminants	Integrated Score	Biological Condition: Benthic IBI	Overall: Integrated Score	County	Location
RT01602							3			5	5	4.3	Beaufort	Upper May River
RT01603							1			5	3	3.0	Colleton	Old Chehaw River
RT01604							3			5	5	4.3	Jasper	Euhaw Creek
RT01606							5			3	5	4.3	Charleston	Cape Romain; Devil's Den Creek
RT01619							5			3	5	4.3	Beaufort	Creek off Trenchard's Inlet
RT01624							5			3	5	4.3	Beaufort	creek off Trenchard's Inlet
RT01625							3			5	5	4.3	Colleton	Fish Creek between Otter and Pine Is.
RT01628							3			3	3	3.0	Dorchester	Ashley River above Magnolia Gardens
RT01633							5			3	5	4.3	Berkeley	Clouter Creek off Cooper River
RT01642							5			5	3	4.3	Charleston	Kiawah Island; eastern tip
RT01643							3			5	5	4.3	Beaufort	Creek off Bull River above St. Helena Sound
RT01644							5			3	5	4.3	Charleston	Clark's Sound
RT01645							5			5	5	5.0	Georgetown	North Inlet; Upper Old Man Creek
RT01646							5			3	5	4.3	Beaufort	Tributary of Bull Creek behind Hilton Head
RT01647							3			5	5	4.3	Charleston	Mullet Hall Creek off Kiawah River
RT01648							5			3	3	3.7	Beaufort	Morgan Island
RT01649							5			5	5	5.0	Charleston	Robbins Creek behind Folly Island
RT01650							5			5	5	5.0	Horry	Creek behind Waites Island
RT01652							5			3	5	4.3	Charleston	tributary off Ocella Creek, Near Botany Bay Island
RT01653							5			3	5	4.3	Beaufort	tributary off Jenkins Creek, on St Helena Island
RT01654							5			3	1	3.0	Georgetown	West confluence of Minim Creek, North Santee River
RT01655							5			3	5	4.3	Georgetown	Tributary of Murrell's Inlet
RT01664							5			5	3	4.3	Beaufort	Creek behind Fripp Island, near marina
RT01665							3			3	3	3.0	Charleston	Dawhoo River
RT01668							3			3	5	3.7	Charleston	Vanderhorst Creek, Bull Bay
NT01598							5			5	5	5.0	Charleston	Shem Creek in Charleston Harbor
NT01599							1			3	3	2.3	Charleston	Brickyard Creek on Ashley River
NT01651							5			5	5	5.0	Beaufort	Creek off Cooper River behind Daufuskie Island

SCECAP 2002 -- Tidal Creeks
Integrated Assessment

Station	Water Quality							Sediment Quality			Biological Condition	Overall	County	Location
	Dissolved Oxygen	Fecal Coliform	pH	Total Nitrogen	Total Phosphorus	Chlorophyll-a	Integrated Score	Toxicity	Contaminants	Integrated Score	Benthic IBI	Integrated Score		
RO026001							5			5	5	5.0	Colleton	Coosaw River near mouth of Combahee River
RO026002							5			5	5	5.0	Beaufort	May River near Calibogue Sound
RO026003							5			5	5	5.0	Beaufort	Beaufort River near Spanish Point
RO026004							5			5	5	5.0	Georgetown	Mouth of South Santee River
RO026005							5			5	5	5.0	Beaufort	Coosaw River near mouth of Bull River
RO026006							5			3	5	4.3	Beaufort	Old House Creek near Fripp Inlet
RO026007							5			5	5	5.0	Beaufort	Coosaw River south of Chisolm Island
RO026008							5			5	5	5.0	Charleston	Five Fathom Creek near Bull Bay
RO026009							5			5	5	5.0	Beaufort	Calibogue Sound near mouth of Cooper River
RO026010							3			1	1	1.7	Georgetown	Winyah Bay near mouth of Minim Creek
RO026011							5			5	5	5.0	Jasper	Wright River north of Mud River
RO026012							3			5	5	4.3	Georgetown	Winyah Bay near mouth of Sampit River
RO026013							5			3	5	4.3	Charleston	West Bank Creek near North Edisto River
RO026014							5			3	5	4.3	Berkeley	Wando River near Juba Island
RO026016							5			3	5	4.3	Charleston	Charleston Harbor east of Ft. Johnson
RO026017							5			5	5	5.0	Beaufort	Broad River below Whale Branch
RO026018							5			5	5	5.0	Beaufort	Broad River near Daws Island
RO026019							3			5	3	3.7	Colleton	Combahee River near Williman Islands
RO026020							5			5	5	5.0	Beaufort	Skull Creek behind Hilton Head
RO026021							5			3	5	4.3	Beaufort	Chechessee River NW of Lemon Island
RO026022							5			5	5	5.0	Beaufort	Mouth of Beaufort River
RO026023							5			5	5	5.0	Beaufort	Colleton River near Daws Island
RO026024							5			5	5	5.0	Horry	Little River in the ICWW
RO026025							5			5	5	5.0	Colleton	Rock Creek near Ashe Island
RO026026							5			5	5	5.0	Charleston	Crab Bank in Charleston Harbor
RO026027							5			5	5	5.0	Colleton	Rock Creek near Hutchinson Island
RO026028							5			3	3	3.7	Charleston	Cooper River near old Navy base
RO026029							5			3	3	3.7	Colleton	Upper South Edisto River North of Sampson Island
RO026030							3			3	5	3.7	Charleston	Ashley River below Koppers Creek
RO026151							5			5	5	5.0	Jasper	Broad River above Whale Branch
RO026290							5			5	5	5.0	Berkeley	Cooper River across from NOAA Pier Romeo
NO026302							5			3	5	4.3	Berkeley	Deyten's Shipyard on Wando River

SCECAP 2002 -- Tidal Creeks
Integrated Assessment

Station	Water Quality: Dissolved Oxygen	Water Quality: Fecal Coliform	Water Quality: pH	Water Quality: Total Nitrogen	Water Quality: Total Phosphorus	Water Quality: Chlorophyll-a	Water Quality: Integrated Score	Sediment Quality: Toxicity	Sediment Quality: Contaminants	Sediment Quality: Integrated Score	Biological Condition: Benthic IBI	Overall: Integrated Score	County	Location
RT022002							5			5	5	5.0	Beaufort	Capers Creek off Trenchard's Inlet
RT022004							5			3	5	4.3	Charleston	Back Creek behind Bull Island
RT022005							1			3	5	3.0	Charleston	Fishing Creek off Dawhoo Cut
RT022006							5			5	5	5.0	Charleston	Narrows Creek behind Sullivan's Island
RT022007							5			3	3	3.7	Beaufort	Cotton Island in the mouth of Whale Branch
RT022008							5			5	5	5.0	Charleston	Second Sister Creek off Lighthouse Inlet
RT022009							5			5	3	4.3	Jasper	East Branch of Boyd's Creek off Beaufort River
RT022013							5			5	5	5.0	Beaufort	Broomfield Creek off Beaufort River
RT022015							5			5	5	5.0	Beaufort	Oak Island Creek near Bull River
RT022016							5			5	5	5.0	Charleston	Devil's Den Creek in Cape Romain
RT022017							1			5	3	3.0	Colleton	Old Chehaw River near Hwy 162
RT022019							5			5	5	5.0	Colleton	Fish Creek near Otter Island
RT022021							3			5	5	4.3	Charleston	Sand Creek off of Steamboat Creek
RT022022							3			5	5	4.3	Beaufort	Broad Creek in Hilton Head
RT022027							5			5	5	5.0	Beaufort	Sparrow Nest Creek off Morgan River
RT022028							5			3	3	3.7	Berkeley	Yellow House Creek off Cooper River
RT022030							5			5	3	4.3	Berkeley	Old House Creek off Guerin Creek
RT022152							3			3	3	3.0	Jasper	Upper Wright River below Turn Bridge Boat Ramp
RT022153							5			5	1	3.7	Beaufort	Upper Okatie River
RT022154							5			5	3	4.3	Charleston	Creek off Stono River near Clemson Ag Station
RT022155							3			5	5	4.3	Charleston	Bass Creek behind Kiawah Island
RT022156							5			5	5	5.0	Beaufort	Capers Creek off Trenchard's Inlet
RT022157							5			5	5	5.0	Beaufort	Warsaw Island in Jenkins Creek
RT022160							5			5	5	5.0	Beaufort	Mackay Creek behind Hilton Head Island
RT022162							5			5	3	4.3	Charleston	Foster Creek off Wando River
RT022164							5			5	5	5.0	Charleston	Bull Narrows behind Bull Island
RT022165							5			3	3	3.7	Beaufort	Haulover Creek off Whale Branch
RT022167							5			3	5	4.3	Colleton	New Chehaw River NE of Boulder Island
RT022170							5			3	5	4.3	Charleston	Creek between Folly River and Robbins Creek
RT022171							5			5	5	5.0	Charleston	Creek at Point of Pines on North Edisto
RT022282							5			5	3	4.3	Berkeley	Clouter Creek off Cooper River
NT022301							3			1	1	1.0	Charleston	Shem Creek below Coleman Blvd Bridge

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